

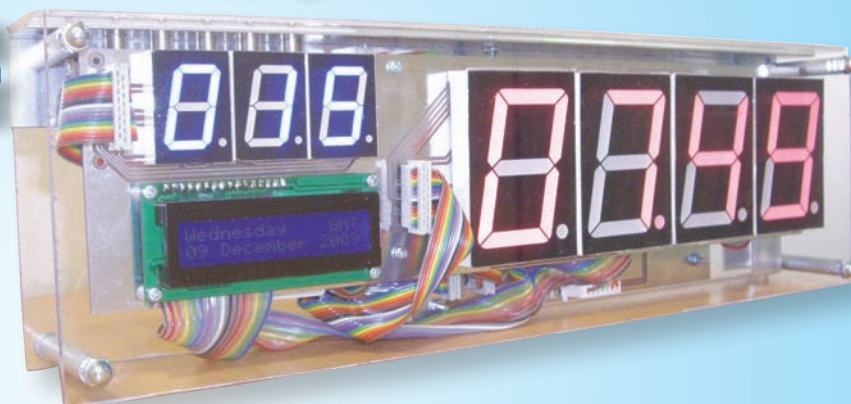
THE No 1 UK MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

EPE EVERYDAY PRACTICAL ELECTRONICS

www.epemag.com

WORKING DAYS ALARM CLOCK

- ★ Day, date, month, year and BST/GMT
- ★ Working days left to the end of the year
- ★ Automatic calculation of leap years, BST/GMT and bank holidays



CHARGE CONTROLLER FOR 12V LEAD-ACID BATTERIES

Provides automatic control, cyclic and float charging



LOW-COST LPT-TO-I²C INTERFACE FOR DEBUGGING

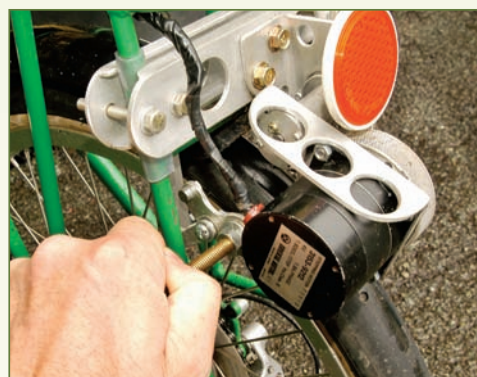
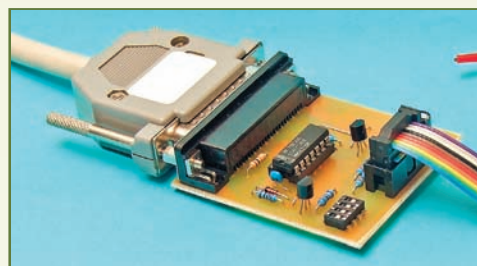
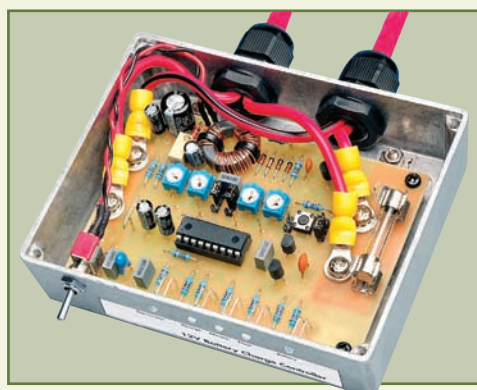
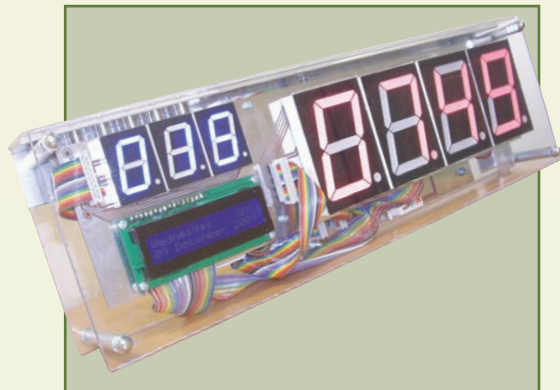
Designed to work with the Philips/NXP debugging program

RECYCLE IT!

Make a super bicycle light alternator from a salvaged stepper motor

\$8.75 US \$10.25 CAN
FEB 2010 PRINTED IN THE UK





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Our March 2010 issue will be published on Thursday 11 February 2010, see page 80 for details.

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PIC & ATMEL Programmers

We have a wide range of low cost PIC and ATMEL Programmers. Complete range and documentation available from our web site.

Programmer Accessories:

40-pin Wide ZIF socket (ZIF40W) £14.95
18Vdc Power supply (PSU120) £19.95
Leads: Parallel (LDC136) £3.95 / Serial (LDC441) £3.95 / USB (LDC644) £2.95

NEW! USB & Serial Port PIC Programmer




USB/Serial connection. Header cable for ICSP. Free Windows XP software. See website for PICs supported. ZIF Socket and USB lead extra. 18Vdc.

Kit Order Code: 3149KT - £49.95

Assembled Order Code: AS3149 - £59.95

NEW! USB 'All-Flash' PIC Programmer



USB PIC programmer for all 'Flash' devices. No external power supply making it truly portable. Supplied with box and Windows XP Software. ZIF Socket and USB lead not incl.

Assembled Order Code: AS3128 - £49.95

Assembled with ZIF socket Order Code:

AS3128ZIF - £64.95

'PICALL' ISP PIC Programmer



Will program virtually all 8 to 40 pin serial-mode AND parallel-mode (PIC15C family) PIC microcontrollers. Free Windows software. Blank chip auto detect for super fast bulk programming. Optional ZIF socket.

Assembled Order Code: AS3117 - £29.95

Assembled with ZIF socket Order Code:

AS3117ZIF - £44.95

ATMEL 89xxx Programmer




Uses serial port and any standard terminal comms program. 4 LED's display the status. ZIF sockets not included. Supply: 16Vdc.

Kit Order Code: 3123KT - £27.95

Assembled Order Code: AS3123 - £37.95

Introduction to PIC Programming



Go from complete beginner to burning a PIC and writing code in no time! Includes 49 page step-by-step PDF Tutorial Manual, Programming Hardware (with LED test section), Win 3.11—XP Programming Software (Program, Read, Verify & Erase), and 1 rewritable PIC16F84A that you can use with different code (4 detailed examples provided for you to learn from). PC parallel port.

Kit Order Code: 3081KT - £16.95


Assembled Order Code: AS3081 - £24.95

PIC Programmer Board



Low cost PIC programmer board supporting a wide range of Microchip® PIC™ microcontrollers. Requires PC serial port. Windows interface supplied. Kit Order Code: K8076KT - £39.95

PIC Programmer & Experimenter Board



The PIC Programmer & Experimenter Board with test buttons and LED indicators to carry out educational experiments, such as the supplied programming examples. Includes a 16F627 Flash Microcontroller that can be reprogrammed up to 1000 times for experimenting at will. Software to compile and program your source code is included.


Kit Order Code: K8048KT - £39.95

Assembled Order Code: VM111 - £59.95

Controllers & Loggers

Here are just a few of the controller and data acquisition and control units we have. See website for full details. 12Vdc PSU for all units: Order Code PSU445 £7.95

USB Experiment Interface Board




5 digital input channels and 8 digital output channels plus two analogue inputs and two analogue outputs with 8 bit resolution.

Kit Order Code: K8055KT - £38.95

Assembled Order Code: VM110 - £64.95

Rolling Code 4-Channel UHF Remote



State-of-the-Art. High security. 4 channels. Momentary or latching relay output. Range up to 40m. Up to 15 Tx's can be learnt by one Rx (kit includes one Tx but more available separately). 4 indicator LED's. Rx: PCB 77x85mm, 12Vdc/6mA (standby). Two & Ten Channel versions also available.

Kit Order Code: 3180KT - £49.95

Assembled Order Code: AS3180 - £59.95

Computer Temperature Data Logger



Serial port 4-channel temperature logger. °C or °F. Continuously logs up to 4 separate sensors located 200m+ from board. Wide range of free software applications for storing/using data. PCB just 45x45mm. Powered by PC. Includes one DS1820 sensor.

Kit Order Code: 3145KT - £19.95

Assembled Order Code: AS3145 - £26.95

Additional DS1820 Sensors - £3.95 each

Most items are available in kit form (KT suffix) or pre-assembled and ready for use (AS prefix).

4-Ch DTMF Telephone Relay Switcher

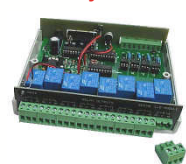


Call your phone number using a DTMF phone from anywhere in the world and remotely turn on/off any of the 4 relays as desired. User settable Security Password, Anti-Tamper, Rings to Answer, Auto Hang-up and Lockout. Includes plastic case. 130 x 110 x 30mm. Power: 12Vdc.

Kit Order Code: 3140KT - £74.95

Assembled Order Code: AS3140 - £89.95

8-Ch Serial Port Isolated I/O Relay Module




Computer controlled 8 channel relay board. 5A mains rated relay outputs and 4 opto-isolated digital inputs (for monitoring switch states, etc). Useful in a variety of control and sensing applications. Programmed via serial port (use our new Windows interface, terminal emulator or batch files). Serial cable can be up to 35m long. Includes plastic case 130x100x30mm. Power: 12Vdc/500mA.

Kit Order Code: 3108KT - £64.95

Assembled Order Code: AS3108 - £79.95

Infrared RC 12-Channel Relay Board



Control 12 onboard relays with included infrared remote control unit. Toggle or momentary. 15m+ range. 112 x 122mm. Supply: 12Vdc/0.5A

Kit Order Code: 3142KT - £59.95

Assembled Order Code: AS3142 - £69.95

Audio DTMF Decoder and Display



Detect DTMF tones from tape recorders, receivers, two-way radios, etc using the built-in mic or direct from the phone line. Characters are displayed on a 16 character display as they are received and up to 32 numbers can be displayed by scrolling the display. All data written to the LCD is also sent to a serial output for connection to a computer. Supply: 9-12V DC (Order Code PSU445). Main PCB: 55x95mm.

Kit Order Code: 3153KT - £34.95

Assembled Order Code: AS3153 - £44.95

Telephone Call Logger



Stores over 2,500 x 11 digit DTMF numbers with time and date. Records all buttons pressed during a call. No need for any connection to computer during operation but logged data can be downloaded into a PC via a serial port and saved to disk. Includes a plastic case 130x100x30mm. Supply: 9-12V DC (Order Code PSU445).

Kit Order Code: 3164KT - £54.95

Assembled Order Code: AS3164 - £69.95

Hot New Products!

Here are a few of the most recent products added to our range. See website or join our email Newsletter for all the latest news.

4-Channel Serial Port Temperature Monitor & Controller Relay Board

4 channel computer serial port temperature monitor and relay controller with four inputs for Dallas DS18S20 or DS18B20 digital thermometer sensors (£3.95 each). Four 5A rated relay channels provide output control. Relays are independent of sensor channels, allowing flexibility to setup the linkage in any way you choose. Commands for reading temperature and relay control sent via the RS232 interface using simple text strings. Control using a simple terminal / comms program (Windows HyperTerminal) or our free Windows application software. Kit Order Code: 3190KT - **£69.95**
Assembled Order Code: AS3190 - **£84.95**



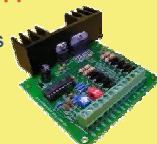
40 Second Message Recorder

Feature packed non-volatile 40 second multi-message sound recorder module using a high quality Winbond sound recorder IC. Stand-alone operation using just six onboard buttons or use onboard SPI interface. Record using built-in microphone or external line in. 8-24 Vdc operation. Just change one resistor for different recording duration/sound quality. sampling frequency 4-12 kHz. Kit Order Code: 3188KT - **£28.95**
Assembled Order Code: AS3188 - **£36.95**
120 second version also available



Bipolar Stepper Motor Chopper Driver

Get better performance from your stepper motors with this dual full bridge motor driver based on SGS Thompson chips L297 & L298. Motor current for each phase set using on-board potentiometer. Rated to handle motor winding currents up to 2 Amps per phase. Operates on 9-36Vdc supply voltage. Provides all basic motor controls including full or half stepping of bipolar steppers and direction control. Allows multiple driver synchronisation. Perfect for desktop CNC applications. Kit Order Code: 3187KT - **£39.95**
Assembled Order Code: AS3187 - **£49.95**



Video Signal Cleaner

Digitally cleans the video signal and removes unwanted distortion in video signal. In addition it stabilises picture quality and luminance fluctuations. You will also benefit from improved picture quality on LCD monitors or projectors. Kit Order Code: K8036KT - **£32.95**
Assembled Order Code: VM106 - **£49.95**



Motor Speed Controllers

Here are just a few of our controller and driver modules for AC, DC, Unipolar/Bipolar stepper motors and servo motors. See website for full details.

DC Motor Speed Controller (100V/7.5A)



Control the speed of almost any common DC motor rated up to 100V/7.5A. Pulse width modulation output for maximum motor torque at all speeds. Supply: 5-15Vdc. Box supplied. Dimensions (mm): 60Wx100Lx60H. Kit Order Code: 3067KT - **£17.95**
Assembled Order Code: AS3067 - **£24.95**

Computer Controlled / Standalone Unipolar Stepper Motor Driver

Drives any 5-35Vdc 5, 6 or 8-lead unipolar stepper motor rated up to 6 Amps. Provides speed and direction control. Operates in stand-alone or PC-controlled mode for CNC use. Connect up to six 3179 driver boards to a single parallel port. Board supply: 9Vdc. PCB: 80x50mm. Kit Order Code: 3179KT - **£15.95**
Assembled Order Code: AS3179 - **£22.95**



Computer Controlled Bi-Polar Stepper Motor Driver

Drive any 5-50Vdc, 5 Amp bi-polar stepper motor using externally supplied 5V levels for STEP and DIRECTION control. Opto-isolated inputs make it ideal for CNC applications using a PC running suitable software. Board supply: 8-30Vdc. PCB: 75x85mm. Kit Order Code: 3158KT - **£23.95**
Assembled Order Code: AS3158 - **£33.95**



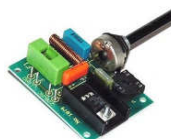
Bidirectional DC Motor Speed Controller

Control the speed of most common DC motors (rated up to 32Vdc/10A) in both the forward and reverse direction. The range of control is from fully OFF to fully ON in both directions. The direction and speed are controlled using a single potentiometer. Screw terminal block for connections. Kit Order Code: 3166v2KT - **£22.95**
Assembled Order Code: AS3166v2 - **£32.95**



AC Motor Speed Controller (700W)

Reliable and simple to install project that allows you to adjust the speed of an electric drill or 230V AC single phase induction motor rated up to 700 Watts. Simply turn the potentiometer to adjust the motors RPM. PCB: 48x65mm. Not suitable for use with brushless AC motors. Kit Order Code: 1074KT - **£14.95**
Assembled Order Code: AS1074 - **£23.95**



See www.quasarelectronics.com for lots more motor controllers



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Also available: 30-in-1 £19.95, 50-in-1 £29.95, 75-in-1 £39.95 £130-in-1 £44.95 & 300-in-1 £69.95 (see website for details)



Tools & Test Equipment

We stock an extensive range of soldering tools, test equipment, power supplies, inverters & much more - please visit website to see our full range of products.

Two-Channel USB Pc Oscilloscope

This digital storage oscilloscope uses the power of your PC to visualize electrical signals. Its high sensitive display resolution, down to 0.15mV, combined with a high bandwidth and a sampling frequency of up to 1GHz are giving this unit all the power you need. Order Code: PCSU1000 - **£399.95**



Personal Scope 10MS/s

The Personal Scope is not a graphical multimeter but a complete portable oscilloscope at the size and the cost of a good multimeter. Its high sensitivity - down to 0.1mV/div - and extended scope functions make this unit ideal for hobby, service, automotive and development purposes. Because of its exceptional value for money, the Personal Scope is well suited for educational use. Order Code: HPS10 - **£129.95**
£169.95
See website for more super deals!



Most items are available in kit form (KT suffix) or assembled and ready for use (AS prefix).



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Secure Online Ordering Facilities • Full Product Listing, Descriptions & Photos • Kit Documentation & Software Downloads

EVERYDAY PRACTICAL ELECTRONICS FEATURED KITS

February 2010

Everyday Practical Electronics Magazine has been publishing a series of popular kits by the acclaimed Silicon Chip Magazine Australia. These projects are 'bullet proof' and already tested down under. All Jaycar kits are supplied with specified board components, quality fibreglass tinned PCBs and have clear English instructions. Watch this space for future featured kits.

Jaycar
Electronics

ROLLING CODE IR KEYLESS ENTRY SYSTEM KIT

KC-5458 £19.00 plus postage & packing

Features two independent door strike outputs and recognises up to 16 separate key fobs. This advanced system keeps coded key fobs synchronised to the receiver and compensates for out of range random button presses. Supplied with solder masked and silk screen printed PCB, two programmed micros, remote fob case, battery and all electronic components. The receiver requires a 12VDC 1.5A power supply. Some SMD soldering is required.

Featured in EPE Aug/Sept 2009

HIGH CURRENT MOTOR SPEED CONTROLLER KIT

KC-5465 £26.25 plus postage & packing

Controls a 12 or 24VDC motor at up to 40A continuous and features automatic soft-start, fast switch-off and a 4-digit display to show settings. Speed regulation is maintained even under heavy loads and the system includes an overload warning buzzer and a low battery alarm. Kit contains PCBs and specified electronic components.

Featured in EPE Jan 2010

HIGH ENERGY IGNITION SYSTEM KIT

KC-5442 £27.75 plus postage & packing

This advanced and versatile ignition system is suited for both two & four stroke engines. Used to modify the factory ignition timing or as the basis for a stand-alone ignition system with variable ignition timing, electronic coil control and anti-knock sensing. Kit includes PCB with overlay, programmed micro, electronic components, & die cast box.

Requires controller (e.g. KC-5386 £19.75) for programming.

- Timing retard & advance over a wide range
- Suitable for single coil systems
- Dwell adjustment
- Single or dual mapping ranges
- Max & min RPM adjustment

Featured in EPE Sep-Nov 2009

Also available to suit: Ignition Coil Driver Kit KC-5443 £13.75

CD-ROM AUDIO PLAYBACK ADAPTOR KIT

KC-5459 £19.00 plus postage & packing

Put those old CD-ROM drives to good use as CD players using this nifty adaptor kit. The adaptor accepts signals from common TV remote controls enabling drive audio functions to be controlled as easily as a normal CD player. Features pre-programmed micro controller, and IDC connectors to the included display panel. Supplied with solder masked and screen-printed PCB and required electronic components.

Featured in EPE Jan 2010

UHF REMOTE CONTROLLED MAINS SWITCH KIT

KC-5462 £29.00 plus postage & packing

Commercial remote control mains switches are generally limited to a range of 20m. This UHF system will operate up to 200m and is perfect for remote power control systems etc. Including a handheld controller, this kit is supplied with cases, screen printed PCBs, RF modules and electronic components. Requires replacement UK socket, see last month's EPE for details.

Featured in
EPE Jan
2010

FAST NI-MH BATTERY CHARGER KIT

KC-5453 £12.50 plus postage & packing

Ideal for RC enthusiasts who burn through a lot of batteries. Capable of handling up to 15 of the same type of Ni-MH or Ni-Cd cells. Build it to suit any size cells or cell capacity and set your own fast or trickle charge rate. Features overcharge protection and temperature sensing. Kit includes solder mask & overlay PCB, programmed micro and specified electronic components. Case, heatsink and battery holder not included.

As published in
EPE August 2009

SMS CONTROLLER MODULE KIT

KC-5400 £17.00 plus postage & packing

Control appliances and receive alert notification from anywhere. It controls up to eight devices by sending plain text messages and simultaneously monitors four digital inputs. It works with old Nokia handsets such as the 5110, 6110, 3210, and 3310, which can be bought inexpensively. Kit supplied with manual, PCB, pre-programmed microcontroller and all electronic components. Requires a common Nokia data cable found in many retail stores.

Featured in EPE March 2007

PIC LOGIC PROBE KIT

KC-5457 £5.00 plus postage & packing

Operating on 2.8-15VDC, this logic probe is suitable for use on the most modern circuits. Extremely compact with SMT devices on a PCB only 5mm wide. It's capable of picking up a pulse only 50mS long and will also detect and hold infrequent pulses when in latch mode. Kit includes PCB and all specified electronic components including pre-programmed PIC. You'll need to add your own case and probe - a clear ballpoint pen and a darning needle work well.

Featured in EPE July 2009

VOLTAGE MONITOR KIT

KC-5424 £6.75 plus postage & packing

Monitors either the battery voltage, airflow meter or oxygen sensor in your car. This versatile 12VDC kit features a 10 LED bar graph that indicates the measured voltage in 9-16V, 0-.5V or 0-1V ranges. Features fast response time, high input impedance and auto dimming for night time driving. Kit includes PCB with overlay and all electronic components.

Featured in EPE November 2007

GALACTIC VOICE SIMULATOR KIT

KC-5431 £13.50 plus postage & packing

Be the envy of everyone at the next Interplanetary Conference. Effect and depth controls allow you to simulate anything from the metallically-endowed C-3PO, to the hysterical ranting of the Daleks. The kit includes PCB with overlay, enclosure, speaker and all components.

Featured in EPE August 2008

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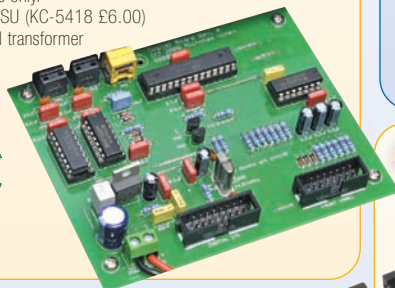
AUDIO KITS FOR ELECTRONIC ENTHUSIASTS

STEREO DIGITAL TO ANALOGUE CONVERTER KIT

KC-5487 £40.50 plus postage & packing

If you listen to CDs through a DVD player, you can get sound quality equal to the best high-end CD players with this DAC kit. It has one coaxial S/PDIF and two TOSLINK inputs to connect a DVD player, set-top box, DVR, computer or any other linear PCM digital audio source. It also has stereo RCA outlets for connection to a home theatre or hi-fi amplifier. This kit requires some SMD soldering skills. See website for full specifications.

- Short form kit with I/O, DAC and switch PCB and on-board components only.
- Requires: PSU (KC-5418 £6.00) and toroidal transformer



SD CARD SPEECH RECORDER & PLAYER KIT

KC-5481 £21.75 plus postage & packing

Use this kit to store your WAV files on MMC/SD/SDHC cards. It can be used as a jukebox, a sound effects player or an expandable digital voice recorder. You can use it as a free-standing recorder or in conjunction with any Windows, Mac or Linux PC. Short form kit includes overlay PCB, SD card socket and electronic components.



AV SIGNAL BOOSTER KIT

KC-5350 £31.95 plus postage & packing

You may experience some signal loss when using long AV cables. This kit will boost your composite, S-Video and stereo audio signals, preserving them for the highest quality transmission to your home theatre, projector or large screen TV. Kit includes case, PCB, silk-screened punched panels and all electronic components with clear English instructions. Requires 9VAC wall adaptor.



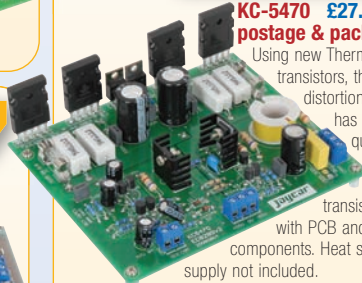
As published in EPE March 2006

ULTRA-LOW DISTORTION AMPLIFIER MODULE KIT

KC-5470 £27.75 plus postage & packing

Using new ThermalTrak power transistors, this ultra-low distortion amplifier module has no need for a quiescent current adjustment or a Vbe multiplier transistor. Kit supplied with PCB and all electronic components. Heat sink and power supply not included.

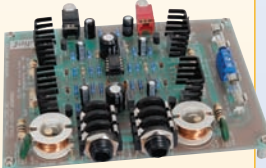
Output power: 135WRMS @ 8 ohms & 200WRMS @ 4 ohms
Frequency response: 4Hz to 50kHz, 1m
Harmonic distortion: <0.008% @ 20Hz-20kHz



STEREO HEADPHONE DISTRIBUTION AMPLIFIER KIT

KC-5417 £10.25 plus postage & packing

Drives one or two stereo headphones from any line level (1 volt peak to peak) input. The circuit features a facility to drive headphones with impedances from about 8-600Ω. Comes with PCB and all electronic components.

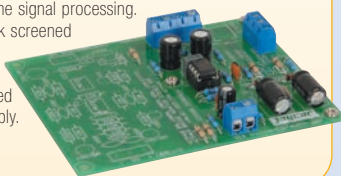


Featured in EPE November 2009
Also recommended: Box HB-6012 £2.00
Power Supply Kit KC-5418 £6.00

BRIDGE MODE ADAPTOR KIT FOR STEREO AMPLIFIERS

KC-5469 £8.25 plus postage & packing

Enables you to run a stereo amplifier in 'Bridged Mode' to effectively double the power available to drive a single speaker. There are no modifications required on the amplifier as this clever kit does the signal processing. Supplied with silk screened PCB and components. Requires balanced (+/-) power supply.

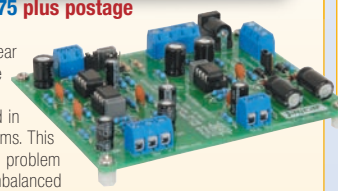


BALANCED TO UNBALANCED AUDIO CONVERTER KIT

KC-5468 £9.75 plus postage & packing

Standard audio gear does not have the balanced inputs and outputs found in professional systems. This kit overcomes the problem by adapting an unbalanced input to balanced output and vice versa. This allows domestic equipment to be integrated into a professional installation while maintaining the inherent high immunity to noise pick-up on long cable runs provided by balanced lines.

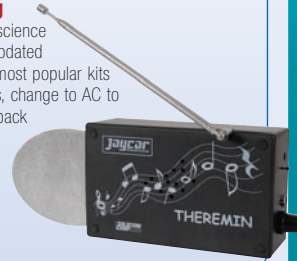
- PCB and all electronic components included
- ±9-15VDC, or 9-30VDC, or 7-12VAC



THEREMIN SYNTHESIZER KIT - MKII

KC-5475 £21.75 plus postage & packing

Create your own eerie science fiction sound effects! Updated features to one of our most popular kits include extra test points, change to AC to avoid switchmode plugpack interference, and a new skew control to vary audio tone. Contains PCB with overlay, pre-machined case and all specified components.



Heatsink to suit
HH-8590 £5.75



Heatsink to suit
HH-8590 £5.75



Heatsink to suit
HH-8590 £5.75



Heatsink to suit
HH-8590 £5.75



Heatsink to suit
HH-8590 £5.75



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Happy New Year!

Carrying on from a theme I started in last month's editorial, perhaps 2010 will be the year when British engineering starts its ascent back to where it rightfully belongs, at the heart of the economy of a fantastically inventive country.

This thought was prompted by an article I read recently in a Sunday paper, as well as a question from a friend. The article noted that to reinvigorate our manufacturing sector we need to find 600,000 engineers over the next seven years – all with advanced skills – to enable us to match our rivals in other developed countries. However, the report highlighted a worrying decline in not only the number of lecturers teaching engineering and manufacturing, but also the number of students applying for related courses.

Clearly, this is not the way to build a second 'workshop of the world' – but we can all play a small part in reversing this trend. As engineers, whether amateur or professional, we do tend to be modest about our talent and ability, and 'hide' the sheer fun of designing and building some pretty sophisticated circuits, devices and projects. If you know young people who show promise in this direction, then do encourage them. Explain to them the rewards of a satisfying and intellectually stimulating career. Not only are we going to need all the technical talent we can muster for our future prosperity, but also you can encourage them toward engineering safe in the knowledge that you are advising someone to enter a fascinating and vitally important profession.

My friend's question was simple, a colleague's daughter was coming to the end of an engineering degree and wanted advice on which area of engineering to head for. There is no right answer to this question, but I know young people are particularly concerned about the environment and so I suggested power engineering, a discipline where making the right decisions will be especially important for all of us.

A happy and successfully engineered new year to you all!

Min

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A number of projects and circuits published in *EPE* employ voltages that can be lethal. You should not build, test, modify or renovate any item of mains-powered equipment unless you fully understand the safety aspects involved and you use an RCD adaptor.

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We do not supply electronic components or kits for building the projects featured, these can be supplied by advertisers.

We advise readers to check that all parts are still available before commencing any project in a back-dated issue.

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NEWS

A roundup of the latest Everyday
News from the world of
electronics



Freeview HDTV springs into action **By Barry Fox**

Parts of the UK will get Freeview terrestrial HDTV in the spring. Viewers will need a completely new receiver, which exploits Europe's DVB-T2 system – and the UK will be the first country in the world to use T2.

Korean company Humax looks likely to be first with T2 receivers. The HD-Fox T2 set-top box will cost £170 and receive either existing DVB-T or new T2 broadcasts, with either MPEG-2 or MPEG-4/H.264 compression.

From launch – promised for mid Q1 – the T2 box will also decode and play audio, video and photos from USB-connected storage using MP3, MP4, JPEG and Xvid codecs (but not Windows Media formats). An over-the-air upgrade, due after launch, will allow TV recording to USB storage. The T2 box also upscales standard definition TV to 1080p full HD.

DVB-T2 uses COFDM with 256 QAM modulation, to get 32Mbps per channel, instead of 64 QAM for 24Mbps or 16 QAM for 16Mbps, as used for Europe's current COFDM DVB-T/MPEG-2 system. It is hoped that more powerful error correction, and the higher transmission powers made possible by the UK's rolling analogue switch-off, will prevent digital breakup of T2 signals in all but fringe areas.

Unfortunately, the Freeview launch announcement was staged at the BBC, and only a small and unlikely mix of technical and lifestyle journalists were invited, with little chance

to ask key questions; for instance, how existing aerials are likely to perform?

"We couldn't accommodate everyone" was all Freeview's PR spokeswoman would say.

Worryingly, Freeview's Powerpoint contained a timeline, which showed receiver development continuing all through 2010 and well past the service launch date. Fortunately, Humax's commercial director Graham North was able to reassure a few days later by demonstrating Freeview HD transmissions using a finished box the size of a paperback book, and saying he is "very confident" of getting enough DVB-T2 chips to support a launch "mid Q1".

Humax also confirmed the unwelcome news that the BBC will invoke copy protection, which will allow the box to record an HD programme to HDD or USB memory, but the recording cannot then be copied or played on another box.

Following the Freeview announcement, Graham Plumb, acting controller, BBC Distribution Operations Group, shared one concern he has: "There is a very important message to get across to consumers. You need to look for new TVs or boxes carrying the Freeview HD logo. If your existing telly has a Freeview logo and an HD Ready logo, that doesn't mean it will receive Freeview HD (unless you buy a separate Freeview HD box)."

A Freeview HD logo exists, but has not yet been promoted to consumers. Graham North

believes this is because making consumers aware of new hardware due next year could dampen Christmas sales of current Freeview hardware.

Says Freeview. "There will be increased visibility as we ramp up to our consumer launch and viewers see it on the product and in marketing materials."

At the Humax demonstration, Bob Hannon, Humax chief technologist and Michael Caghey, technical service manager at Humax, also showed a beta version of the BBC's iPlayer catchup TV service displayed on a consumer TV direct from a broadband-connected Humax satellite receiver designed for Freesat, the UK's free-to-air satellite service. MPEG-4 streaming quality on a large LCD TV was very good, even at 1.6Mbps. The BBC plans a higher rate of around 3Mbps, for HD streaming.

Although the Humax Freesat box has a built-in HDD, it cannot record the iPlayer stream and the only HD output is protected HDMI. But the standard definition RGB and composite outputs are unprotected, so can be copied by connection to a DVD recorder. This undermines the BBC restrictions on iPlayer streams and limited-life downloads (usually seven days) which are in place to protect DVD sales at a later stage.

"The BBC have to show best effort" says North.

Space pioneer awarded Faraday Medal

Sir Martin Sweeting of Surrey Satellite Technology Ltd (SSTL) has been awarded the Faraday Medal, the Institution of Engineering and Technology's (IET) most prestigious award, for his outstanding contribution to the advancement of satellite technology.

Sir Martin commented on the award, "It gives me great pleasure to receive this award and I hope that it may inspire young engineers to challenge conventions and pursue their ideas with conviction. The space industry has changed a great deal since I was a research student, with space technologies developing rapidly, and I am delighted that the UK's engineers continue to push the boundaries at the forefront of satellite innovation."

Sir Martin started his career in the mid-1970s as a young communications researcher at the University of Surrey. At a time when space exploration was something only countries with

enormous aerospace budgets, such as the US and the (then) Soviet Union could pursue, Sir Martin believed that it could be done cheaper and more quickly. Together with a small team of fellow researchers, he decided to experiment by creating a satellite using standard consumer technology, known as 'commercial off-the-shelf' (COTS) components.

That first satellite, UoSAT-1 (University of Surrey satellite) was launched in 1981 with the help of NASA, who had become very interested in the group's work. The mission was a great success, outliving its planned three-year life by more than five years. Most importantly, the team showed that relatively small and inexpensive satellites could be built rapidly to perform successful, sophisticated missions.

Sir Martin founded SSTL in 1985, and his pioneering approach to the design, build, launch and operation of satellites has

propelled SSTL to the forefront of the global small satellite industry, fundamentally changing the economics of space. Today, he is the Executive Chairman of SSTL, which employs 300 people and has now launched 34 spacecraft, he also chairs the Space Centre at the University of Surrey.

He continues to look to the future, commenting, "I am interested to use the innovative techniques developed at Surrey to reach beyond Earth's orbit and reduce the cost and increase the tempo of space exploration. It is a long-held dream of mine to launch an affordable UK mission to the Moon".

That possibility is coming closer to reality, with SSTL being chosen as the prime contractor for the UK's lunar mission, MoonLITE, and being recently selected by ESA to manage the European Student Moon Orbiter Mission.

Bletchley Park Grant

THE Heritage Lottery Fund (HLF) has given the green light to the Bletchley Park Trust to work up plans to help transform Bletchley Park into a world-class heritage and educational centre. Development funding of £460,500 was awarded to help progress their plans.

The HLF first-round pass means that the Bletchley Park Trust can now progress to the second stage of the HLF application process. They have up to two years to submit more detailed plans and apply for approximately £4.1 million of HLF support that they are seeking for their £10 million project.

Historians agree that Bletchley Park, the top secret codebreaking hub of World War Two, shortened the war by two years, saving countless lives. Since 1994, it has been open to the public as a museum. Interest in the site continues to grow with visitor numbers almost doubling from 50,000 a year, three years ago, to

approaching 100,000 this year. Bletchley Park Trust has a thriving educational programme, and last year over 6,000 schoolchildren visited the museum. Post-war, very little was done to Bletchley Park in the way of maintenance or repairs, and the buildings on the site had fallen into a critical condition. English Heritage and Milton Keynes Council recently announced investment of £930,000 to deal with this, and restoration work is well underway.

The plans that Bletchley Park Trust are seeking HLF support for, are to transform the current museum into a world-class heritage and educational site, reflecting the profound significance of the impact that its work had on the outcome of war and as a permanent tribute to its unsung intellectual warriors.

Welcoming the award, Simon Greenish, director of the Bletchley Park Trust, said "The support offered by HLF is a landmark

event for the Trust in our quest to provide a permanent future for Bletchley Park that will enable us to work up detailed plans for the education and enjoyment of future generations.

Since 1992, the Trust has fought fiercely and tirelessly for this victorious moment; not only for the vital investment needed to move our plans forward, but also for this definitive endorsement from the UK's most prestigious heritage funding body, that the nation has confidence, belief and advocacy in the Trust and the restoration project. However, this is not the end, nor the beginning of the end, but it is perhaps the end of the beginning.

As Churchill said at the end of war in Europe: "We may allow ourselves a brief period of rejoicing; but let us not forget for a moment the toil and efforts that lie ahead. We must now devote all our strength and resources to the completion of our task."

MOTOR CONTROL

Two new low-cost motor control development systems have been announced by Microchip. Both development boards feature the flexible dsPIC33F 'MC' DSC families, which integrate leading-edge motor control features. In addition, Microchip has produced five royalty – and license – free application notes, aiding engineers in creating motor applications that run at peak efficiency and generate maximum torque using the minimum amount of energy.

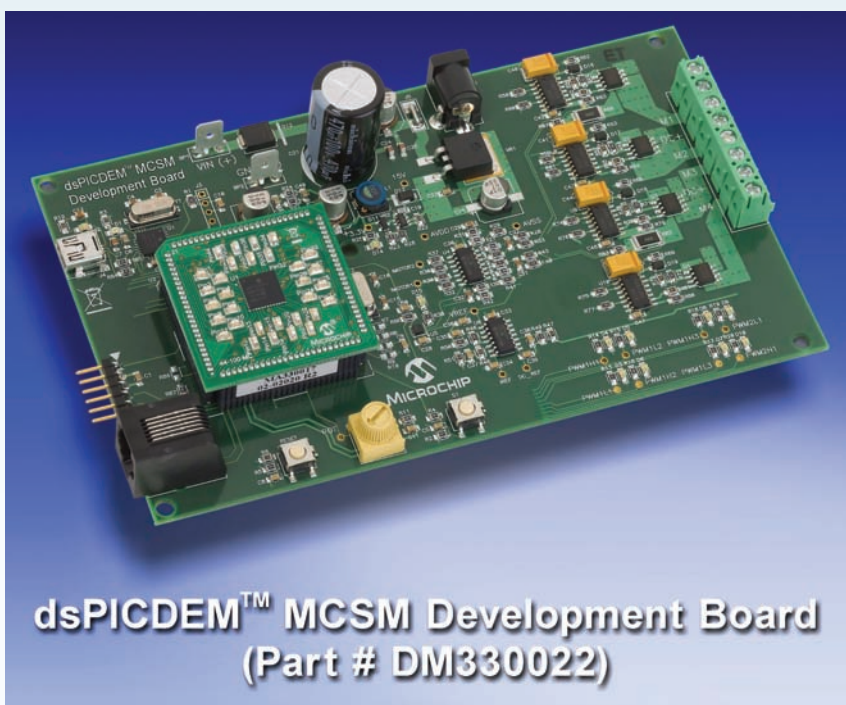
The new dsPICDEM MCHV Development System is a development tool for the rapid evaluation and design of a wide variety of high-voltage, closed-loop motor control applications using AC induction motors, brushless DC motors or permanent magnet synchronous motors. The board includes in-circuit debugging circuitry, eliminating the need for a separate debugger for development with Microchip's dsPIC33 Motor Control DSC families.

The new dsPICDEM MCSM Development Board is a cost-effective tool for creating unipolar and bipolar stepper motor applications. This board enables the rapid development of both open-loop and current-closed-loop microstepping routines using Microchip's dsPIC33 Motor Control families.

Along with related application notes and free source-code software, Microchip's free MPLAB IDE integrated development environment includes an application called the Data Monitoring and Control Interface (DMCI), which promotes rapid parameter tuning for different motors. Microchip's free Field Oriented Control (FOC) software

libraries and stepper motor control library further enable the development of green motor-based systems and high-speed stepper motor control applications.

For more information see www.microchip.com.



RADIO SOCIETY

The Dorking District Radio Society are keen to increase their membership (younger members are particularly welcome) and they have an open invitation for anyone to come along to meetings.

They meet at the Friends' Meeting House, Butterhill, Dorking, RH4 2LE on the fourth Tuesday of each month at 19:45. They operate an 80 metre net on Sundays at 08:15hrs, c.3772kHz SSB and a 2 metre net on Thursdays at 20:00hrs 144.775MHz FM.

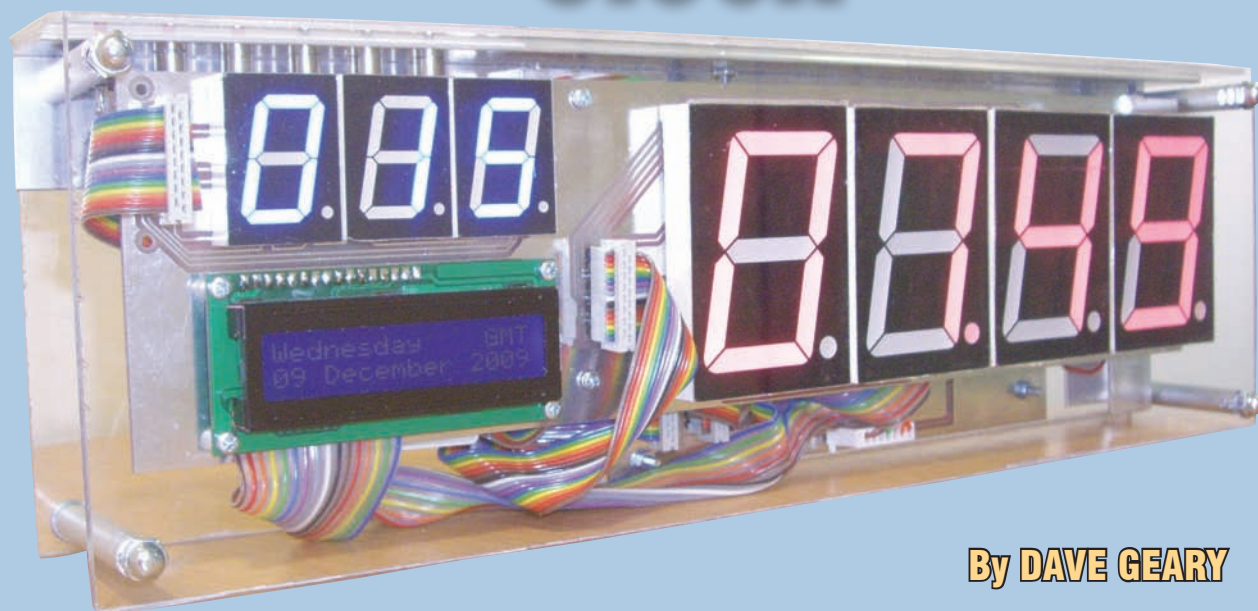
The club website is www.ddrs.org.uk and secretary David Smith can be contacted by email at: ddrs.secretary@yahoo.co.uk, or by phone on 07808 579501.

Radio and computer rally

Wythall Radio Club's 25th Annual Radio and Computer Rally will be held on Sunday, 21 March 2010 at Woodrush Sports Centre, Shawhurst Lane, Hollywood, Nr Wythall, Birmingham B47 5JW.

The rally includes: radio and computer traders; massive bring and buy; refreshments; all under cover in sports halls; good on-site parking; only two miles from J3 M42; open 10am to 3pm; admission £1.50; talk in S22. See www.wrcrally.co.uk.

Working Days Alarm Clock



By **DAVE GEARY**

In addition to displaying the time, this alarm clock also displays the working days left to the end of the year; day; date; month; year, with automatic calculation of leap years, BST/GMT and bank holiday adjustment.

I'VE ALWAYS had a fascination with electronic clocks, perhaps from my teenage years when I bought one of the first LED alarm clocks, together with an LED watch that was so fashionable at the time. Recently, I moved offices and my new home is much more modern in design than my old one, and somehow the round, analogue wall clock wasn't going to look quite right among the pastel shades, chrome and glass.

Business has become much more targetted and specific, those targets have become tighter and more difficult to achieve, and so a simple way of understanding the number of working or trading days until the end of the year would be useful. The design

started as a clock, became a clock with a 'working days left' display, and then became an alarm clock too!

The nature of my work means I am out of this new found commercial splendour for much of the time, so a clock needs to be accurate and self-adjusting for British Summer Time (BST). It's one thing to show off your latest design in the office, but if it doesn't work, reputations quickly get ruined!

I live in England, so calculating working days based on English bank holidays is one thing, but for publication, version two required the flexibility to operate in other countries. Even in the four countries that make up the UK bank holidays differ and, occasionally, can change.

Bank holidays

This section refers to English bank holidays, but hopefully illustrates some universal points as well. Some are static, the same day every year. Examples are New Years Day (January 1), Christmas Day (December 25) and Boxing Day (December 26).

Others are defined by month and day of the week; for example, the last Monday in August, and the first and last Mondays in May. Finally, there are those which are defined by more complex rules, such as Easter. Easter is defined as '...the Sunday after the first full moon on or after the day of the vernal equinox'. Easter Monday and Good Friday follow Easter Sunday. Fortunately, with a bit of research

Main Features

- 24 hour, easy-to-read, large clock display
- Flashing colon
- Alarm active indicator
- Three-digit display of working days left until December 31
- LCD display of day, date, month, year, and BST/GMT (if set to UK)
- Automatic calculation of leap years
- Automatic calculation and time adjustment of British Summer time (BST) when set to UK
- Automatic calculation of English bank holidays if set to UK-England, with options for other countries, including, where applicable, adjustment for bank holidays falling on weekends
- Country selection stored in EPROM (stored in EPROM in case of power failure)
- Ability to enter up to 40 non-working days manually
- Alarm clock function with up to nine different settings, including day of week (all days, plus working or non-working days)
- Chirp alarm function for a one second alarm at the same time, every day
- Ten minute snooze on all alarms
- Ten minute snooze alarm available at anytime
- Clock trimming function to adjust fast/slow running
- Internal siren, operates at +5V or +10V (+10V recommended for directly connected sounders)

on the Internet, a formula was found that can calculate when Easter will occur for a given year.

British summer time (BST)

In the UK, we have a tradition of adjusting time forward by one hour during '...the period beginning at one o'clock, Greenwich mean time, in the morning of the last Sunday in March and ending at one o'clock, Greenwich mean time (GMT), in the morning of the last Sunday in October'. Given that being able to calculate first and last days is part of the bank holiday requirement, it becomes a fairly simple matter to check when BST starts and finishes. If the country selected during set up is the UK, then this GMT/BST adjustment is automatic.

Technical overview and features

The circuit design is fairly straightforward (Fig.1), with a PIC18F4550 run by a 20MHz crystal and the usual LCD connections, LCD backlight, and pull down resistors for pushbuttons. There are, however, a couple of notable points.

The use of large LED displays requires a supply greater than 5V, and so two 7805 regulators are used to provide a +5V and +10V supply; the upper regulator using the output of the lower one as a ground reference. This arrangement complicates the control of the large LEDs via a

ULN2003 transistor array; even at logic 0, a PIC output will be sitting at least at half supply in relation to true 0V in this circuit, which will light the LED segments. The coupling of the PIC to the transistor array must, therefore, be AC rather than DC, so coupling capacitors are used rather than the normal base resistors.

The alarm output is controlled, for similar reasons, by a PNP bipolar power transistor, with the option of either a +5V or +10V potential. It is recommended you use the 10V output, selected by connection on the PCB, for any output requiring significant current, including the specified siren.

The diagram does not show the wiring of the display PCBs, which simply commons all of the segment anodes and provides them through multiway connectors to ribbon cables to R9-R15 inclusive. Cathodes are brought out individually to these connections and are driven by the ULN2003 (via R4, R5, R6 for the working days displays). Resistors R14 and R15 limit current to decimal points on the large red displays.

Software overview

The PIC software was written in MikroC with a few lines of assembler where required. The basic program is simple; an interrupt is called every 1.6ms, which both multiplexes the display and counts time. Periodically,

flags are set, which cause displays to be updated and, in some cases, calculations to be performed. Once per minute, during the interrupt function, a counter is incremented that counts the number of minutes elapsed from midnight on January 1 (minutes_from_1stJan).

The main() function carries out the following tasks on power up:

- Configure ports, INTCON, disable port pullups, make sure the alarm sounder is off
- Display the initial message on the LCD display
- Read the trimming fast/slow variable from EPROM
- Make sure all alarm data is cleared and all nine alarms are off

It then moves on to a continuous loop within the function. The loop contains routines or calls to routines that carry out the following:

- Read and action buttons;
 - i) call set_time()
 - ii) call trim_timebase()
 - iii) call alarm_set()
 - iv) set a time for a snooze alarm
 - v) cancel a sounding alarm and/or clear the snooze alarm
- Once per minute:
 - increment a counter which keeps track of minutes
 - set an hour flag every 60 minutes
 - adjust displayed time if British summer time mode is set
 - calculate current day number

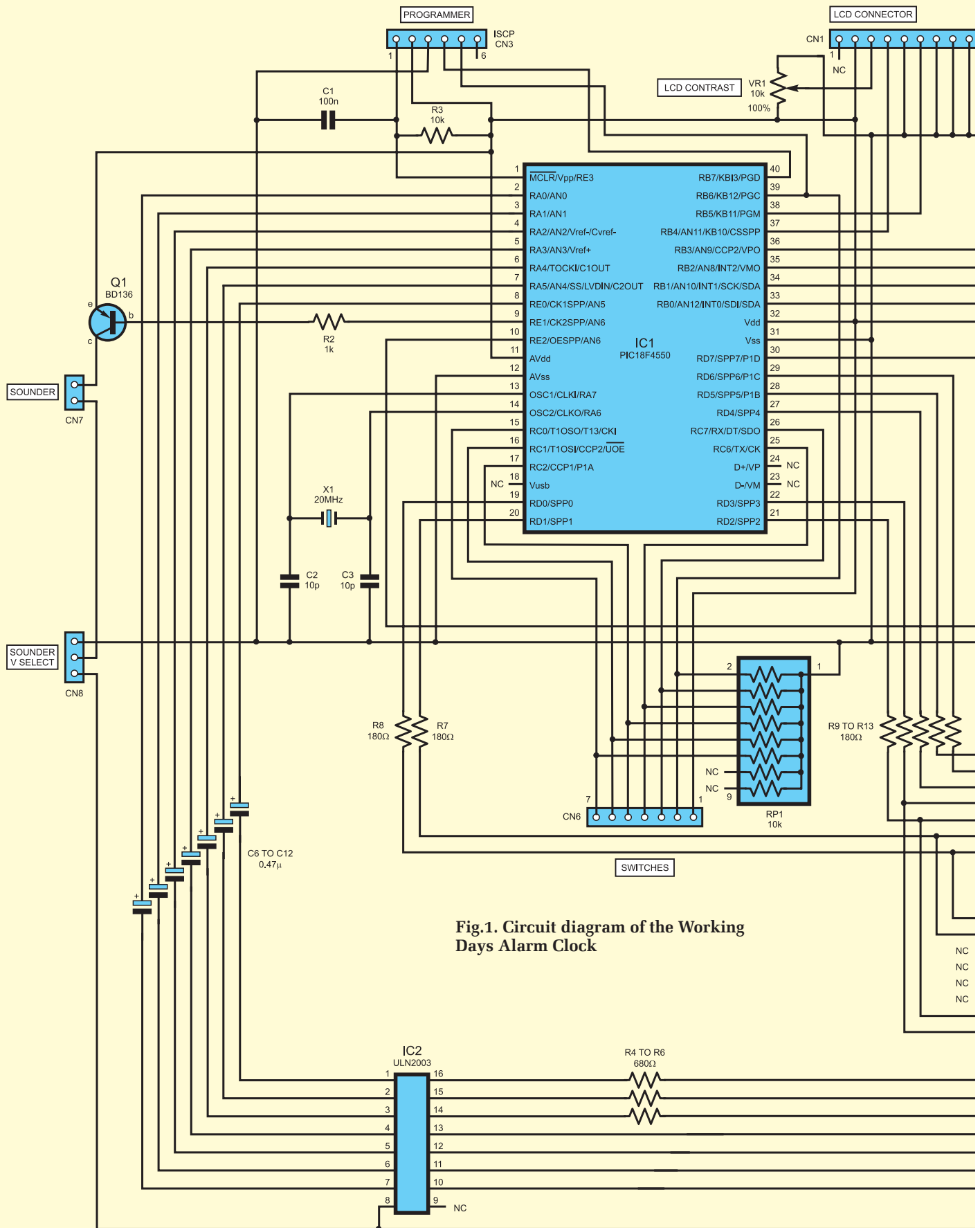
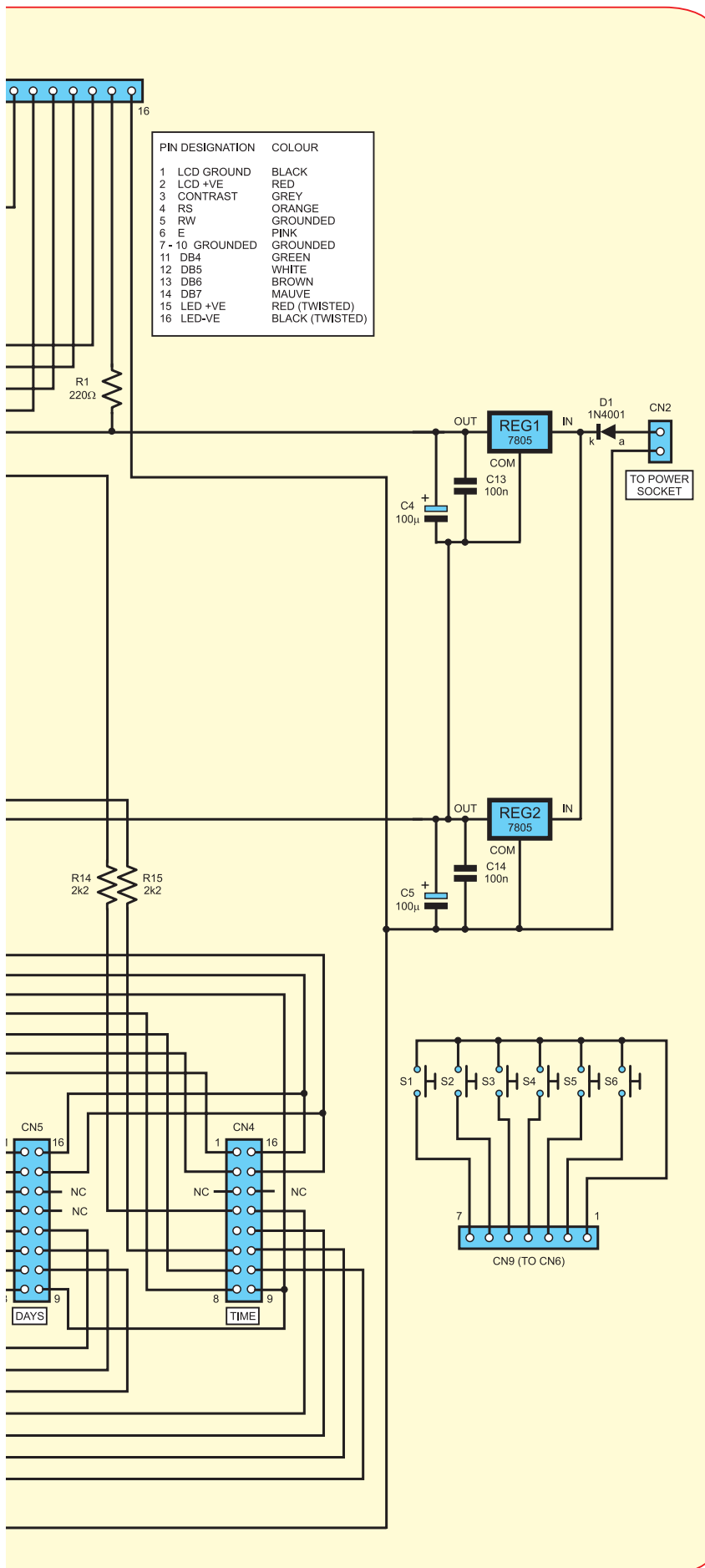


Fig.1. Circuit diagram of the Working Days Alarm Clock



calculate current hours and minutes per digit ready for display
check all nine alarms against new time and activate alarm if necessary
check snooze alarm against new time and activate alarm if necessary

- Once per hour;
set a day flag every 24 hours at midnight
check if British summer time has been reached and, if necessary, set BST mode
- Once per day;
call a daily display routine (see below)
check if the end of the year has been reached and set a flag if it has
- Once per year;
reset seconds, minutes, hours increment year
carry out the daily display routine

The time display is therefore updated and the alarm times checked against the current time once per minute, but the other parts of the display only need to be updated once per hour, or even once per day. A routine, `daily_displayRoutine()`, carries out a number of these functions as follows:

- Calculate the number of working days left
- Set a flag if the current day is a working flag to support the alarm options of working day or non-working day
- Calculate each digit of the working days left display and load into global variables that are picked up in the display multiplexing called each interrupt
- Call routines that support the LCD display:
 - i) calculate the current month and date using a routine `day_to_month_and_date()` from the current day number
 - ii) from the month and date, calculate the day of the week
 - iii) call a routine to update the LCD display – `normal_lcd_display()`. This routine in turn calls `display_year()`, `display_month()`, and `display_day()`. The routine also includes code to display the current weekday and indicate BST or GMT.

All of these routines call upon pre-calculated data that is set when the clock is first set using the routine `set_time()`. This routine includes:

- Loading the clock's current time and date, if set, for adjustment
- Code to display prompts on the LCD, read buttons and adjust variables for setting the clock
- Read current Country Code, allow any adjustment and resave to EPROM
- Code to set Manual Non-Working days and store in EPROM, with an option to clear all preset days.

With all this information, `set_time()` then carries out some calculations that are only required once per year or when the time is first set:

- Find out if this year is a leap year (actually placed in the year entry part of the code) using `check_leap_year()`
- Calculate the current day number and adjust if a leap year
- Calculate the number of minutes elapsed from midnight on January 1
- Call `process_year_calcs()` routine which:
 - i) finds the number of non working days using `find_non_working_days()`, outlined below
 - ii) calculate the start and finish of British summer time in terms of the number of minutes from January 1 – these figures are later used by the program to activate this function
 - iii) adjust the BST start and finish variables if the year is a leap year
- Within the clock program, the time is stored in two variables as `minutes_from_1stJan` and `minutes_from_1stJan_adj`. The latter is made equal to the former during GMT, and is advanced by 60 minutes during BST on a once-per-minute check against a flag, `BST_mode`. In this `set_time()` routine, this check is performed immediately, so that the time which appears on the display straight after setting the time is correct, given that it may be BST or GMT when the clock is set

- An immediate calculation is made for each digit of the time display

A complex routine, `find_non_working_days()`, is called by `set_time` and consists of the following:

- Calculates the day number, starting from January 1, of all Saturdays in the year, if the working days per week is five
- Ditto, for Sundays, if the working days per week is either five or six
- Calculates bank holidays depending on the country code set, as in the table shown under Instructions below. This is achieved using, or reusing, functions such as:
 - i) `get_day_number(day, month)`
 - ii) `find_easter()`, which returns Easter Sunday. A full explanation of the formula behind this is outside the scope of this article, but it is implemented in C within this function. For more details, see the acknowledgements at the end of this text
 - iii) a check is included at each stage to see if a calculated bank holiday falls on a Sunday or a Saturday, and if so, the day number found for that bank holiday is incremented to the Monday following the Sunday, or decremented to the Friday preceeding the Saturday
- To all this calculated data, manual non-working days are added to the array
- A checking data routine makes sure that within the array that stores these non-working days, each non-working day number only appears once
- Finally, this draft data is copied into the array used for later calculations

Other routines are relatively straightforward, with the `alarm_set()` and `trim_timebase()` routines, for example, requiring not much more than data entry with LCD prompts, and, in the latter case, EPROM read and write using `ep_read()` and `ep_write()`. The `trim_timebase()` function modifies the interrupt timing once in every 625 calls so allowing a very fine trim of the clock running speed.

Some routines, such as `set/clear_alarm_indicator()` and `set/clear_alarm_output()` reduce the number of lines and make the program more readable.

Note that most variables are set up globally, including the seven segment definitions. While this is not normal for a C program, it makes this program considerably easier and *possibly* faster running, with fewer lines of code. Despite the complexity of the program, there is plenty of RAM and ROM left in the PIC18F4550, and so there is no need to make these variables local and then pass arguments to and from function calls. The seven-segment definitions include a second set identical to the first, but enable the flashing colon by calling, for example, 16 instead of 6 to light the decimal point.

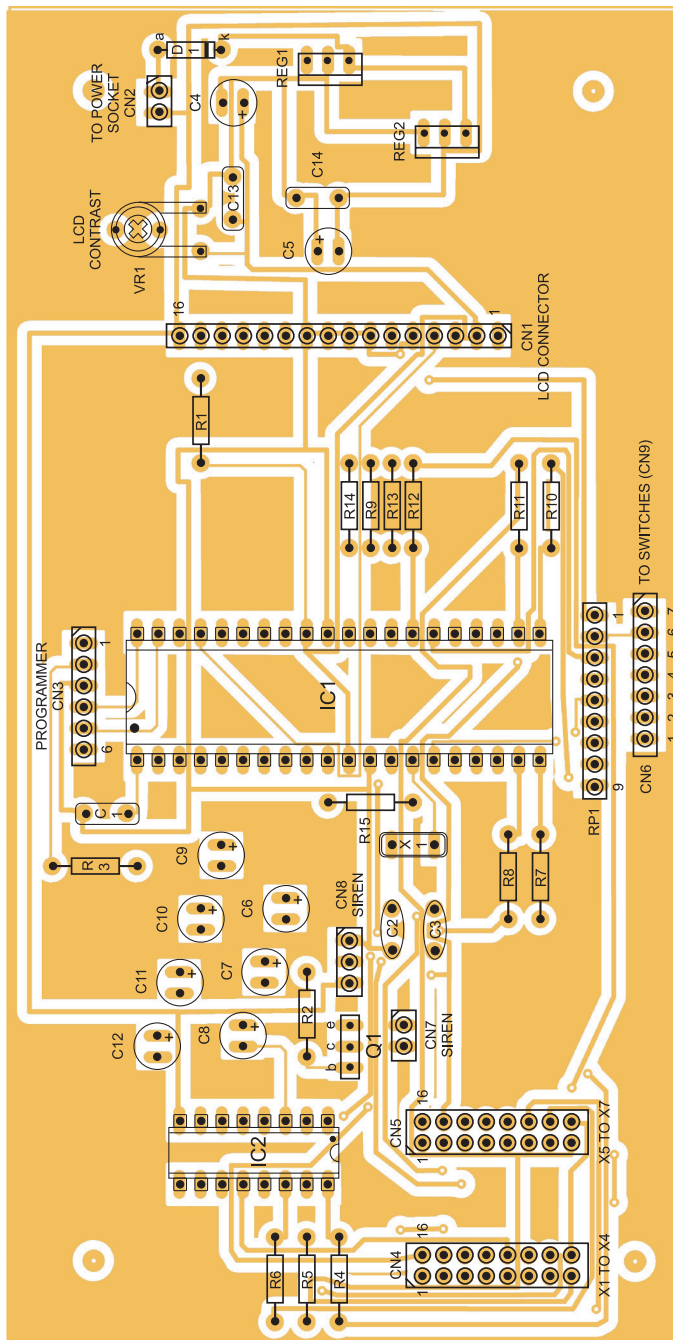
The software is available via the Library section on the *EPE* website at www.epemag.com. Preprogrammed PICs are available from Magenta Electronics – see their advert in this issue.

Construction

The design relies on two double-sided PCBs. Sadly, multiplexed displays do not sit easily on a single-sided PCB without introducing lots of wire links, and this double-sided design avoids them completely. Ribbon cables connect the displays to the main PCB using IDC sockets, with header connectors for all other connections. Note that the LCD display connects to a 16-way in-line pin connector; I could not find a suitable 16-way in-line IDC socket, and so made my own using a small piece of stripboard and a female header.

The use of the *EPE PCB Service* is recommended. However, for those wishing to have a go at making their own double-sided PCBs, they are downloadable in PDF format from the *EPE* website, go to the 'Library'. All spare holes on both PCBs need to be pinned through to achieve connections to the copper foil patterns on both sides. A large number of components and connectors also require soldering on both sides of the PCB. **Make sure the connectors you buy can be soldered on both sides.**

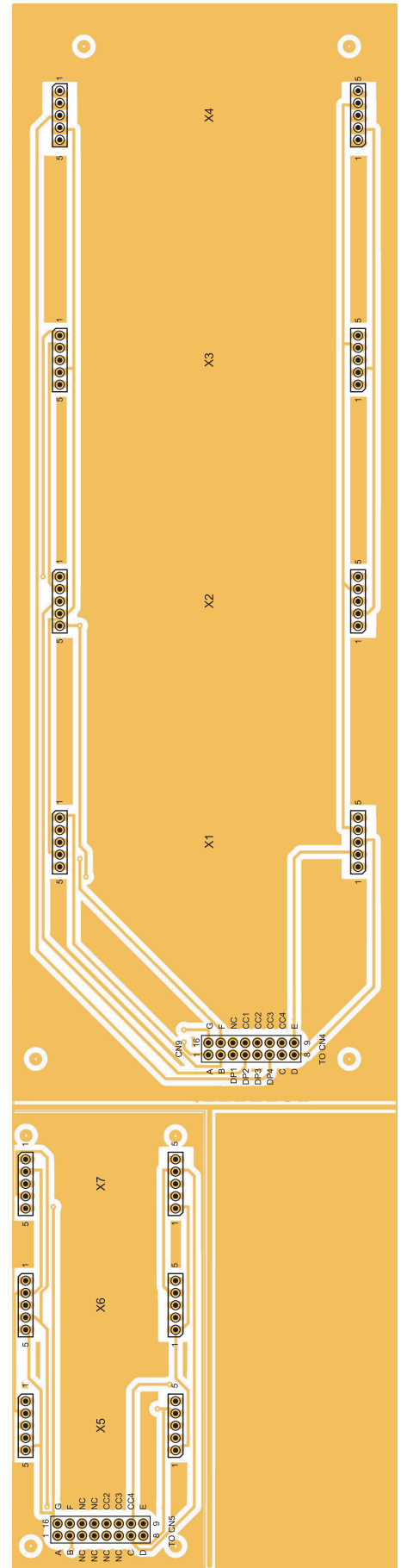
The main PCB component layout is shown in Fig.2. Construction of the PCBs is very simple, and following the



1-SELECT 2-UP 3-DOWN 4-ALARM SET 5-SNOOZE 6-ALARM CANCEL 7-+VE

Fig.2. Main double-sided PCB for the Working Days Alarm Clock, all spare holes need pin-throughs and a number of components and connectors/sockets need soldering to both sides of the PCB. The box under the diagram shows the switch connections.

Fig.3. Display double-sided PCB for the clock, again soldering to both sides of the PCB is required for the sockets



usual rule of resistors first, followed by capacitors and semiconductor sockets and then semiconductors. Be careful of the orientation of IC2, which is upside down. IC Sockets should be used, but make sure the pins are long enough to allow soldering to both sides of the PCB.

The regulators should be mounted fairly low on the board, otherwise the tabs can, if mounted in the same way as the prototype, touch the underside of the display board. On the prototype I put some self adhesive felt 'tabs' on top of them for additional protection.

Display PCB

The display PCB is shown reduced in size in Fig.3. This is designed so that it can be cut into two pieces, allowing the two displays to be mounted in different positions should you so desire. In the prototype, the board was left whole, which also retained a position for the LCD display. Before mounting any LEDs onto the display board, drill holes to mount your LCD module if it is intended to be on the PCB; it's just much easier to do this first rather than last.

Do remember to put the mounting bolts into the display board before you

Parts List – Working Days Alarm Clock

PC boards, code 742 (main) and 743 (display), available from the *EPE PCB Service*, sizes 160mm x 80mm and 350mm x 80mm

- 6 pushbutton, panel mounted, switches: press-to-make, release-to-break (S1 to S6)
- 1 16 pin DIL turned-pin IC socket
- 1 40 pin DIL turned-pin IC socket
- 1 16-way pin header (CN1)
- 2 2-way Molex male and female (CN2, CN7)
- 1 6-way Molex male and female (CN3)
- 2 16-way double row (2x8) pin header, as Farnell 159-3445 (CN4, CN5) (use Farnell 381-5717 with ribbon cable 130-1039)
- 1 7-way Molex male (CN6) and female (CN9)
- 1 3-way Molex male and female (CN8)
- 14 5-way turned-pin sockets for LED display mounting
- 1 two-tone piezo mini-siren (Maplin KU65V or similar)

Ribbon cable from LCD1 to PCB and 16-way female pin connector – see text (Farnell 130-1036)

External power supply 15V DC smoothed or SMPS and suitable panel mounting socket. (A supply capable of providing 150mA plus the sounder current.)

- 2 Perspex 350mm x 110mm x 4mm
- 1 Perspex 350mm x 48.5mm x 2mm

Angle aluminium 30mm x 30mm x 350mm, 2mm thick

'U' shaped aluminium 200mm x 15mm x 15mm, 2mm thick

- 4 aluminium tubes 8mm dia. 8mm long
- 4 aluminium tubes 8mm dia. 50mm long
- 4 4BA bolts, 60mm long
- 4 4BA bolts, 28mm long
- 5 4BA bolts, 10mm long
- 13 4BA nuts
- 4 small self-tapping screws

Connecting wire

Semiconductors

- 1 1N4001 50V 1A rect. diode (D1)
- 2 7805 +5V voltage regulators (REG1, REG2)
- 1 BD136 PNP transistor (Q1)
- 1 PIC18F4550 microcontroller, pre-programmed – see text (IC1)
- 1 ULN2003A Darlington array (IC2)

4 7-segment 2.3in., common cathode, red LED displays (X1 to X4) (Futurlec 7SR23011AS)

3 7-segment 1in., common cathode, blue LED displays (X5 to X7). (eBay **Auspicious.e**) or use green display (Farnell 622-424 or Futurlec 7SG10012AG) – see text

1 2-line by 16 character blue LCD module (Futurlec LCD16x2BL (green) or Blue 16x2BL (blue), or any HD44780 16x12 line module)

1 20MHz crystal (X1)

Capacitors

- 3 100nF ceramic (C1, C13, C14)
- 2 10pF ceramic (C2, C3)
- 2 100µF radial elect. (C4, C5)
- 7 0.47µF radial elect. (C6 to C12)

Potentiometers

- 1 10kΩ horizontal preset (VR1)

Resistors (All 0.25W 1% metal film, except R1)

- 1 220Ω 5W metal film (R1)
- 1 1kΩ (R2)
- 1 10kΩ (R3)
- 3 680Ω (R4 to R6)
- 7 180Ω (R7 to R13)
- 2 2.2kΩ (R14, R15)
- 1 10kΩ SIL 8-way (RP1)



insert the far right-hand LED display, as the head of the bolt sits underneath the display. Make sure that the bolt is lock-nutted in place before final insertion of the display.

Since the inception of this design, one-inch common cathode displays in blue have become more difficult to find, and indeed the only source I have found is a regular eBay shop, Auspicious-e. The design will accept green displays from either Farnell or Futurlec, and of course these can be matched with a green backlit LCD display instead of a blue one.

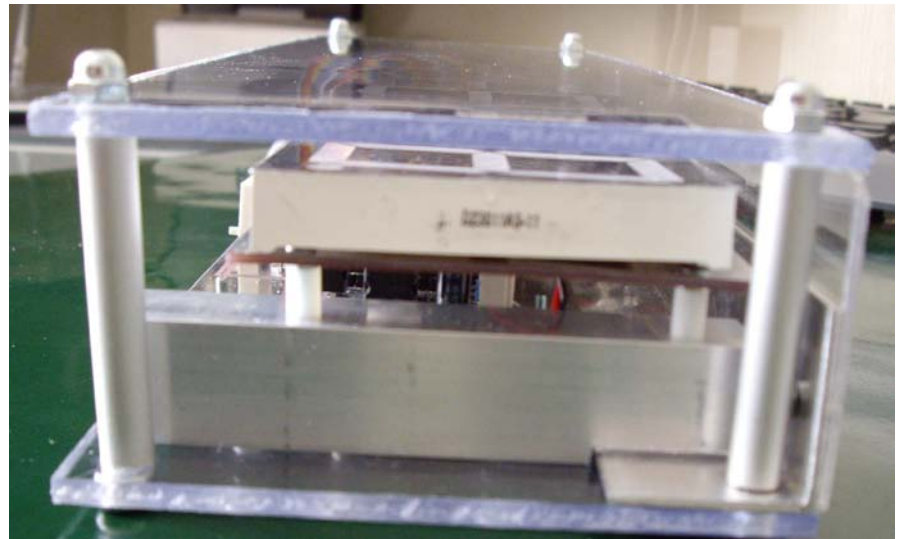
Housing

Having constructed the PCBs, attention can then turn to the housing. The prototype used two pieces of 350×110×4mm Perspex, as used for secondary glazing, a small piece of the same but 2mm thick, and some aluminium angle and c-section. Fig.4 shows plan and cross sectional views of the main components.

Take two pieces of 4mm thick Perspex 350mm × 110mm. Drill a 5mm hole centered 7.5mm from each edge, in each corner, so that you have a 5mm gap from the edge of the hole to the edge of the Perspex. These will form the back and front of the housing. Next, take a piece of aluminium angle, 30mm × 30mm × 2mm, and with one side away from you, mark six pushbutton mounting holes at 15mm centres, starting 15mm from the left and 15mm from the rear edge. Pilot drill these at 2mm or 3mm for the moment.

Then, take a piece of Perspex 350mm × 48.5mm × 2mm thick and mark through the aluminium angle onto this Perspex, such that the rear edge is flush with the rear edge of the aluminium. Drill these, carefully, to around 8mm or 9mm so that the nuts from the pushbuttons will sit inside the hole. Now drill out the aluminium to the proper diameter holes for your pushbuttons.

It should now be possible to mount the pushbuttons on the aluminium angle and position the 2mm Perspex on top of the aluminium. Do this, and secure the Perspex in place with 4BA bolts and nuts; two will suffice, on the right-hand side and one in the middle. Next, place this assembly on the bench and use one of the 4mm Perspex sheets to mark the back of



Side view showing the construction of the clock housing

the aluminium angle. The edge of the 4mm sheet should be flush with the top of the 2mm sheet. Mark and drill out to 5mm.

Assembly

Next, take some 8mm aluminium tube and cut two pieces 49mm long, and two pieces 47mm long. These form sleeves over the 4BA bolts that will hold the clock together. You can now test the assembly by using 4BA × 60mm machine screws and 4BA cap nuts, with the longer, 49mm sleeves at the bottom of the housing and the 47mm sleeves between the aluminium angle and the front of the housing at the top.

Take the display board, and place 8mm spacers over the bolts fitted earlier. Using 15mm × 15mm × 2mm U-section aluminium, create two mounting brackets for the board. To do this, place the U-section with one

face on the back panel of the housing with the aluminium angle in place. The U-section will overhang the aluminium angle and it will be necessary to notch out part of one side so that it can sit flat.

Once done, mark and drill holes in one side of the U-section so that the display board can be mounted to it with 8mm spacers. The board can then be tried in position. Use a fine marker pen to mark the positions of two self-tapping screws in the 4mm Perspex rear panel, and drill a clearance hole. A 3mm screw will be more than adequate. Mark and drill a pilot hole in the aluminium U-section having dismantled it from the display board. Fix the U-section in position to the rear panel temporarily.

This will allow you to position the main board on the back panel so that it sits nicely between the U-sections,

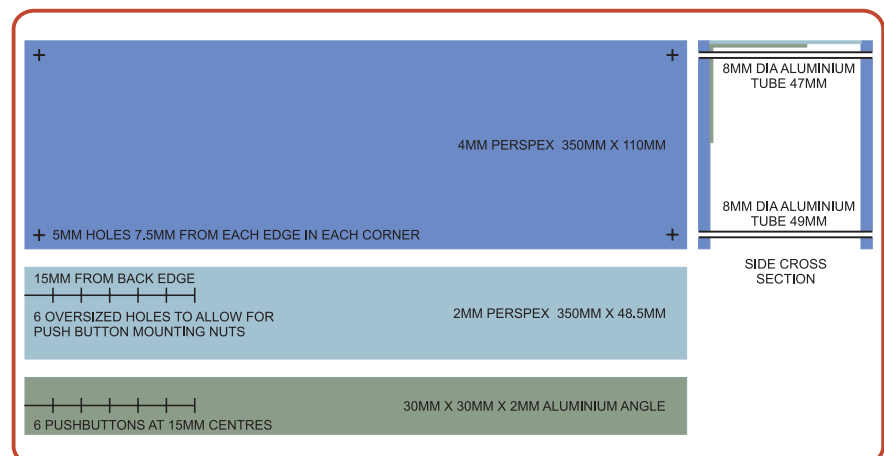


Fig.4. Components and construction of the clock housing

Constructional Project

and the mounting holes do not foul the aluminium angle. Mount the main board on 8mm spacers, and wire the pushbuttons to the Molex connector. The photo shows the prototype mounted on the back panel, being programmed with a PicKit2.

Power socket

Mark, drill, and fix a power socket to the rear panel, and repeat with the buzzer or sounder chosen to the left of the left-hand U-section. Remove the U-section pieces, and reattach them to the display board. It will then be possible to fix the main board in position using the self-tapping screws.

From here, it's a case of plugging together the boards, and remounting the display board. The housing can then be assembled completely using the 4BA machine screws and cap nuts finger tight.

In use – power up

On initial power up, the display will show a test pattern of 123 on the blue displays, followed by 4567 on the rest, with a welcome message on the LCD display. After a short delay, the blue displays will change to ---, the red displays to 0000 and the clock is now ready to be set.

Press Select and use the + and – buttons to select Year, Month, Date, Hours, Minutes and the number of working days in the week, following the prompts on the LCD display. Entering five working days assumes Saturday and Sunday are non-working days, and entering six days assumes Sunday is the non-working day; obviously entering seven days assumes every day is a working day.

Next to be entered is country code. This code affects the working days left counter and the calculation of British summer time (BST) as follows:

Bank Holiday	Country Code
Easter Monday	UK England,
Good Friday	UK England, UK not Eng
December 25	UK England, UK not Eng, Christmas
December 26	UK England, UK not Eng, Christmas
January 1	UK England, UK not Eng
Last Monday In August	UK England
First Monday In May	UK England, UK not Eng
Whit Monday – last Monday in May	UK England, UK not Eng

British summer time is calculated automatically when the country code is UK England, or UK not England.

Next follows the opportunity to select non-working days manually, for example specific religious festivals, your birthday, etc. Buttons change function as follows:

Snooze	–	escapes the entry of manual non-working days
Select	–	if pressed <i>before</i> any day is selected, clears the EPROM of any data
	–	if pressed <i>after</i> a day has been selected, enters this day
'+' or '–'	–	selects a date

Once all the days have been used up (maximum of 40), or the Snooze button has been pressed, the clock then makes a number of calculations of bank holidays, BST/GMT, and non-working days. A check is also made of any bank holidays that fall on weekends so that the preceding Saturday or following Sunday is allocated as a non-working day, and that each non-working day is only counted once. For example, if a manual non-working day coincides with a bank holiday. The display will show calculating, followed by checking, followed by copying, and then will assume the default display of day, date, month, year, and a BST/GMT indicator.

Resetting: If at any time there is a need to adjust the clock, press Select. The clock will then go through the routine as above, starting at the last time the clock showed and using the last entered country code and manual non-working days as defaults.

Alarm: To set up one or more of the nine alarm settings, press Alarm. The LCD display will show Alarm Set and a number bottom right that shows which of the nine alarms you are setting.

Use + or – to select an alarm to set. Press select, and you will be asked to choose a specific day, a working day, a non-working day, a Chirp alarm (one

hours and minutes; to escape this routine (while the LCD display is at Alarm Set) press Snooze, which will exit this mode and return the LCD display to default.

Cancelling the Alarm: To cancel an alarm before it goes off, go through Alarm Set as above and choose Off as the Alarm Day. To cancel during an alarm, press Cancel, which will silence the alarm and extinguish the alarm active indicator, which is the far right hand red decimal point.

To snooze, press Snooze, which will cancel the alarm and enter a new, temporary alarm time in ten minutes. Note that a snooze alarm can be set for ten minutes at any time by pressing the Snooze button.

Trimming: Once the clock is set, it can be sped up or slowed down in steps of ± 1.04 seconds per day, or $\pm 0.0121\%$. To access this function, press + and – together, and then + to speed the clock up, and – to slow it down. The LCD display will show the current trim setting, which is stored in EPROM.

Clocking off

Your clock should now be given pride of place; it certainly has proved a conversation piece in my office. I must resist the urge to keep checking its accuracy against the speaking clock. **EPE**

Acknowledgements

The following websites provided information which was used in the design of this clock:

http://www.direct.gov.uk/en/Governmentcitizensandrights/LivingintheUK/DG_073741

<http://en.wikipedia.org/wiki/Easter>
<http://aa.usno.navy.mil/faq/docs/easter.php>

<http://www.webexhibits.org/calendars/week.html#anchor-certain>

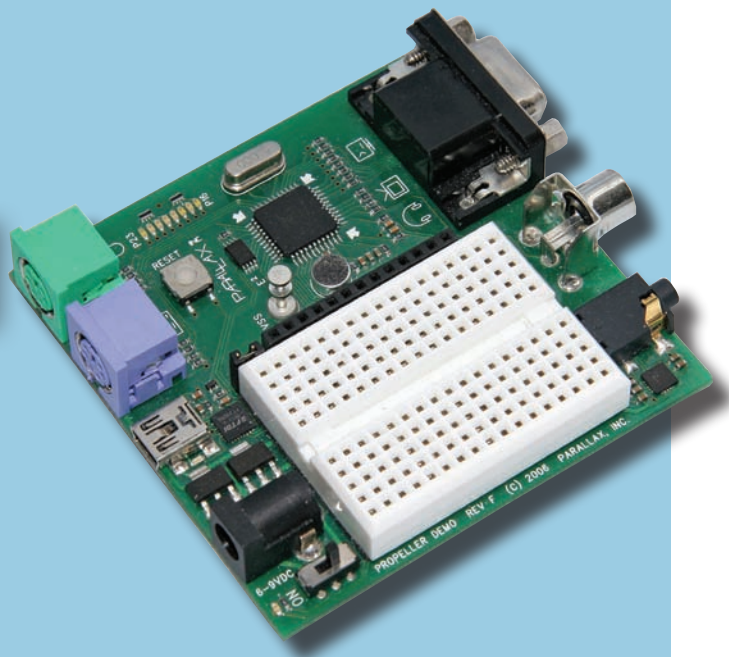
http://en.wikipedia.org/wiki/Calculating_the_day_of_the_week#Useful_concepts

http://katzentier.de/_misc/perpetual_calendar.htm

http://en.wikipedia.org/wiki/British_summer_time

Propeller Demo Board Review

by Robert Penfold



Robert takes the Parallax Propeller Demo Board for a spin!

MUCH of the information about microcontrollers provided in *EPE* relates to the ever-popular PIC range of chips, but there are many other microcontrollers available. The demonstration board reviewed here is based on one of the more interesting of these, and the chip in question is the Propeller microcontroller from Parallax Inc.

The novel feature of this RISC microcontroller is that it contains eight processors, or 'cogs' as they are called in 'Propeller' terminology. These enable the chip to utilise a form of parallel processing. The cogs work in a largely autonomous fashion, but a sort of time-share arrangement is used for access to global memory and the input/output pins.

Where conventionally a main program and (say) four subroutines would be used, with a Propeller chip, the four subroutines would be handled by separate programs, with each one running on its own cog. The main program could be handled by a fifth cog, or it could be broken down into separate routines handled by the four remaining cogs. With eight processors and a maximum clock frequency of 80MHz, the Propeller

chip is certainly very powerful, and is capable of handling practically any application.

Ins and outs

The Propeller chip is available in various 40 and 44-pin encapsulations, with most of the pins being taken up by a 32 line input/output port. The others are used for the usual things, such as the built-in crystal or CR clock oscillator and the reset facility. The 32 input/output lines operate independently, with the direction of each one being set individually. The chip operates from a 3.3V supply, and the port therefore operates at 3.3V, and not the more common 5V logic levels.

Four of the input/output lines have special functions, with two of them being used when programming the chip. These would typically be connected to a PC via a USB/serial converter. The other two 'specials' are used to communicate with a separate 32kB EEPROM chip.

There is also 32kB of internal ROM, but this is used by the internal functions of the chip, such as the boot loader, various tables, and the high-speed interpreter for the chip's high level programming language

called 'Spin'. There is 32kB of built-in RAM, which can be used to store programs when testing and developing software. Once perfected, the software is loaded into the external EEPROM.

Demo board

The Demo board (Fig.1) has a built-in USB interface that connects to the host PC via a standard USB cable with a miniature connector at one end to connect to the board. Many of the Propeller chip's input/output pins are used to provide various ports on the board. These ports use minimal additional hardware, and therefore rely heavily on software routines to get them to do anything useful. There are standard (PS/2 type) PC keyboard and mouse ports, and also a monitor port of the 15-pin VGA variety.

A 2.5mm stereo headphone jack is also provided, together with a phono socket that can be used to provide a TV/video output. The board has an integral electret microphone. There is a 5MHz crystal for the clock oscillator, but this is fitted in a holder so that it can be easily swapped for one having a different resonant frequency.

Power needs

The board is not powered by the USB port, and requires a DC mains adapter that is not supplied with the board. The power connector is an ordinary 2.1mm (centre positive) type. A supply of 6V to 9V at up to about 500mA is required. The use of a non-stabilised supply is not recommended, even though the board has integral regulators for the 3.3V and 5V supplies.

Presumably, the rather high voltages produced by most non-regulated adapters would run the risk of the on-board regulators overheating. My collection of about twenty adapters failed to provide anything with the right characteristics, so I eventually used a borrowed 9V regulated type that gave trouble-free operation.

There are a couple of controls on the board, which are the usual on/off and reset switches. A small (2 × 17 × 5) solderless breadboard is included on the board, plus a connector strip. The latter gives access to the supply rails and to outputs 0 to 7 of the Propeller chip. There is also a large stud-style connector for the 0V supply rail.

The breadboard and connector make it easy to use the board with your own circuits, such as relay drivers and digital-to-analogue converters, but it is perhaps a shame that more lines are not available for user add-ons. The other 24 lines are used for the various built-in ports. Lines 16 to 23 are used for the VGA port, but they also drive on-board LED indicator lights, which can be useful when making some initial experiments with the board.

Software

Installing the software for the Demo board is straightforward and follows the standard Windows scheme of things. The software used to program the Propeller chip is called the Propeller Tool (Fig.2); it is available free of charge from the Parallax website and it is very straightforward in use. It is essentially a simple text editor, with a few added extras.

Most of the screen is taken up by the text area, but the left-hand section shows the available folders of project files and the contents of the selected folder. The Spin programming language is object oriented, and there is

a third panel that shows the loaded objects and their hierarchy.

Simply double-clicking the entry for a project file opens it in the text area. It is possible to have several files open, with each one having its own tab near the top of the screen. There is the usual menu bar at the top of the screen, which provides access to the standard File, Edit, and Help facilities.

Additionally, there is a Run menu that has options for programming the Propeller chip and for identifying the hardware. When first using the board, it is a good idea to use the identification feature to make sure that everything is operating correctly, with the software and the board communicating correctly.

There are options to compile the code and load it into the Propeller chip's RAM or into the EEPROM. Programs are run from the RAM, so code loaded into EEPROM is then loaded into RAM as well by the chip itself. Either way, programs are automatically run once the uploading process has been completed.

Loading programs into RAM is faster than loading them into EEPROM, but the time taken in either case is a

matter of seconds rather than minutes. Of course, programs loaded directly into RAM are lost once the board is switched off. Less obviously, these programs are also lost if the Reset switch is operated, since this results in the RAM being cleared and the contents of the EEPROM, if any, being loaded into RAM.

Documentation

The Demo Board seems to be primarily aimed at those who already have a basic knowledge of the Propeller chip, and would like to start developing more advanced projects. Consequently, anyone starting with this unit, rather than one of the more basic Propeller education kits, is to some extent 'diving in at the deep end'. Unfortunately, there is only one document specifically covering the demonstration board, and this is a circuit diagram that also has a few very brief explanatory notes. The inclusion of a brief 'Getting Started' guide would make it much easier to get the board installed correctly and tested.

In order to make use of the demonstration board it is necessary to have a reasonable understanding of

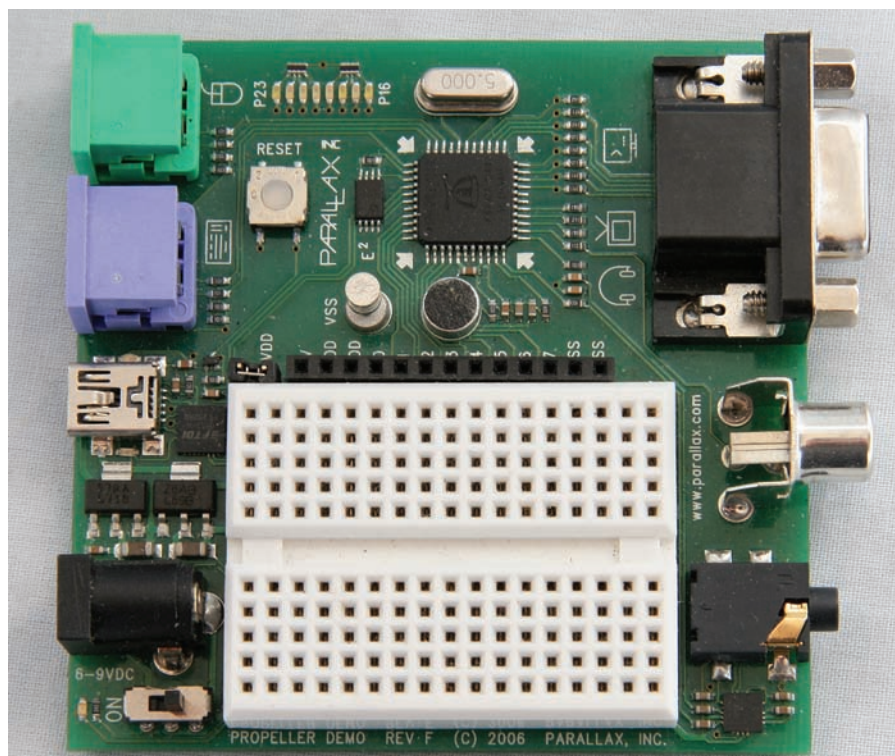


Fig.1. The board has a number of built-in ports, which rely on software routines and use a minimal amount of hardware. The breadboard prototyping area can be used in conjunction with the eight spare input/output lines

electronic hardware, microcontrollers, and computer programming. The same is true of the more simple Propeller education kits, and the Propeller chip is probably not a good starting point for complete beginners. For those with the requisite background knowledge, it is not too difficult to get started with the demonstration board. The documentation for the education kits is included, and this includes numerous simple examples that can be adapted for use with the demonstration board.

There is also a large (438-page) manual for the Propeller chip, which gives details of the hardware side of things, together with details of both the Propeller assembly language and the high-level Spin programming language. Most users will probably settle for using the Spin language, but it is useful to have the option of using assembly language when speed is all-important. Experienced programmers will find plenty that is familiar in these languages, such as the common loop structures in the Spin language.

On the other hand, some aspects of the Propeller chip are decidedly non-standard, and the programmer has to come to terms with the eight cogs and some different ways of doing things. It is quite easy to program the chip to do some basic tasks, but getting it to perform complex real-world tasks could require a fair amount of time and effort. The Propeller chip has the usual support from online forums, and there are open source programs available that should make it easier to develop complex tasks.

Conclusion

The Propeller chip is certainly a very powerful microcontroller, and in many applications it is possible to use one or two cogs, a few input/output lines, and suitable software routines instead of external interface hardware. On the other hand, for many everyday applications its parallel processing is perhaps a bit 'over the top'. However, it is well suited to the more demanding tasks, especially if a minimalist hardware approach is preferred, and it is still a practical proposition for less demanding tasks.

Switching to a new microcontroller is never going to be particularly quick or easy, but the demo board provides a reasonably painless way of familiaris-

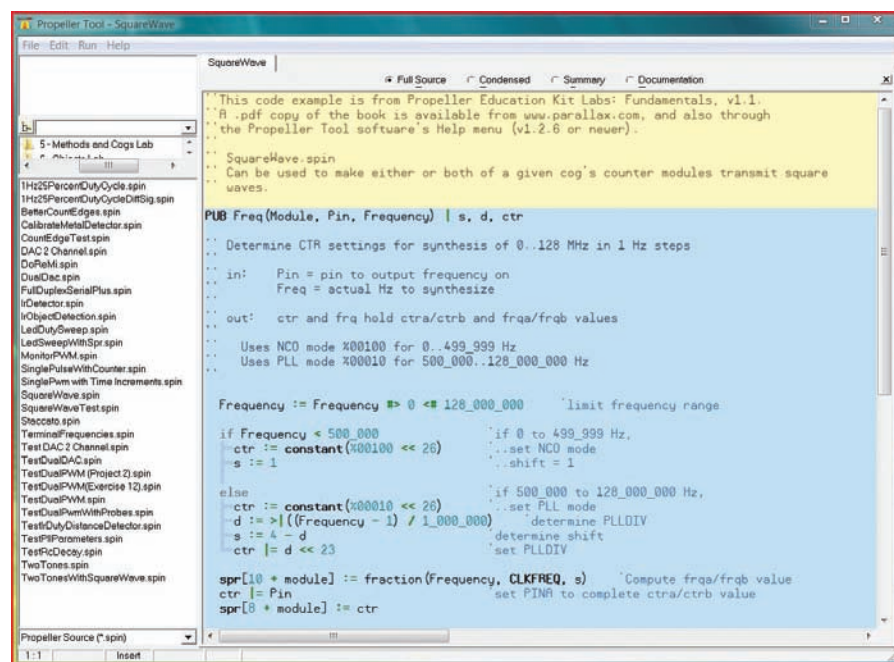


Fig.2. The Propeller Tool software uses a conventional Windows layout. The main panel is a text area where programs are entered and edited, while the panels to the left are used for loading programs and showing the hierarchy of objects

ing yourself with the Propeller chip and its programming languages, and then moving on to the development of practical projects.

While it is useful to have the built-in hardware for various ports such as monitor and keyboard types, these leave the unit with relatively few spare input/output lines. This is clearly a limiting factor when developing units that will use few, if any, of the built-in interfaces.

The board itself is very well made and looks as though it is tough enough to withstand years of regular use. The price is reasonable, and is in line with similar products for other processors. No mains adapter is included with the board, and it is not available as an optional extra either. It therefore has to be purchased separately unless you happen to have something suitable already. A great deal of on-disc documentation is supplied with the board, but as already pointed out; the only documentation that is specific to this product is a circuit diagram. Although the board is not aimed at beginners, a bit more documentation than this would significantly improve the product.

The Spinvent range includes other educational and development kits for the Propeller chip, including some relatively simple education kits. One of these might be a better proposition for someone starting from

scratch with this chip. Bear in mind though, that none of the Propeller kits, including the educational kits, are intended for complete beginners. They all require the user to have some previous knowledge of electronic circuits, microcontrollers, and computer programming.

The Propeller manual is available online as a free download, as is the documentation for the Propeller educational kits. You can therefore study the 'ins and outs' of the chip in detail before deciding whether to go ahead and buy some of the hardware. If you are into microcontrollers and have not encountered the Propeller chip before, I would certainly recommend downloading the documentation and giving this chip serious consideration. It is an interesting device, and I guess many people will be tempted to try it for its 'play value' if nothing else.

Further details of the Propeller Demo Board and a range of other Propeller products can be obtained from: Spinvent, Dept EPE, 38 Nunsfield Road, Buxton, Derbyshire, SK17 7BN. Tel. 07790 879349

Web www.spinvent.co.uk
Email info@spinvent.co.uk

A great deal of helpful information and downloadable documentation is available from the **Parallax Inc** website at: www.parallax.com. **EPE**

Nation Shall Speak Unto Nation – Gratis!

TechnoTalk

Mark Nelson

Ham radio operators were the first DIY group to create an international system for free communication. More recently, hobbyists turned the business model of computing and the Internet on its head by offering open source software, information websites, forums and chat lists for nothing. Now do-it-yourselfers are doing the same for telephone calls, with not just free speech, but a complete alternative telephone infrastructure. Mark Nelson explains the details.

Even if you need reminding what the acronym VoIP stands for, it's a fair certainty that you have heard of Skype and Vonage. Both of these systems offer cut-price (or even free) phone calls using the Internet as the main 'transport' network and Voice over Internet Protocol (VoIP) as the enabling technology. This service is also known as 'Internet telephony' because that's what it is, using the Internet to provide a telephone service, although it needs to be noted that business users route their VoIP calls not via the Internet, but over their own private circuits rented from bandwidth providers.

Coming of age

Looking back, I see that I last covered VoIP in *EPE* in 2005, when internet telephony was still something of a novelty, used by early adopters and the digital cognoscenti. As the International Telecommunications Union (a global United Nations organisation) says, the technology has certainly come of age since then. VoIP, declares the ITU, has gained widespread acceptance among service providers, consumers and businesses, offering a cheaper way to get in touch. Estimates of the total number of VoIP users worldwide vary, with analysts quoting figures of between 90 and 175 million, equivalent to 10 per cent of landline users.

Although a new breed of alternative service providers has grown up, the established telecomms operators have also embraced VoIP technology to save money using IP-based networks. VoIP gives industry newcomers a major advantage because they do not need to establish telephone exchanges everywhere; instead, they just rent bandwidth and use the incumbent telephone operators to deliver their calls to landline and mobile subscribers.

Getting started

Consumers need just a broadband connection to become users. They can then use a headset and their computer to connect to their VoIP provider or more conveniently a 'terminal adapter' (TA) of some sort and plug in an ordinary phone. A major advantage of using a TA is that your computer does not need to be switched on to make and receive internet calls; the TA handles all the processing.

Terminal adapters are compact boxes the size of an external disc drive, and plug into your broadband connection once you have unplugged the cable from your computer

(which is then connected to a socket in the TA). The hook-up is hardly any more complicated if your computer is connected via a wireless router and all service providers provide easy start-up guides.

Answers to questions

Probably your first question is 'what will it cost', and the answer depends on how you intend to use Internet telephony. Skype (www.skype.com) is fundamentally a standalone network, as was the now defunct Free World Dialup and others. Users can call other users on the network for nothing, but if you wish to make a call to (or from) a public landline or mobile phone there are charges. The same applies to Sipgate (www.sipgate.co.uk), although in Sipgate's case the company will give you a free UK (or foreign) landline number and this will cost you nothing if you use this only for incoming calls.

Finally, there are networks such as Vonage (www.vonage.co.uk), which exist only to provide cut-price 'normal' telephone service. For a fixed sum (£5.99 a month with Vonage) you get a free terminal adapter plus unlimited calls to standard UK landline numbers at no extra charge and free calls to other Vonage subscribers around the world. This means you can call friends and relatives effectively for nothing if they also have a Vonage account.

With Internet telephony there is no enforced geographical link between the phone number and the physical location of the telephone. If you live in London but want to have a Glasgow (or New York or Paris) telephone number, so that people in those cities can call you at local rate, this is not a problem. You merely pay the monthly charge on each of the numbers and people 'think' you have a local presence in each of these other locations.

Probably the second thing you'll ask is how easy it is to get started; it really is simple, as you will see if you take a look at www.vonage.co.uk/how-does-vonage-work/. This explanation is written for the Vonage network, but is similar for most other providers.

Downsides?

The main defect of Internet telephony – and it's not a major one – is speech quality. At times, speech can become echoey, intermittent or a bit 'strangled', rather like a poor-quality mobile call. To be fair, it's normally pretty good.

There are some theoretical vulnerabilities, such as eavesdropping by third parties or unwanted re-routing of calls by criminals, but

there is no evidence of any major threat. If you feel like exploring the dark side, take a look at the websites: www.hackingvoip.com/, www.ethicalhacker.net/content/view/127/24/ and www.blackhat.com/presentations/bh-usa-06/BH-US-06-Endler.pdf.

The C*NET alternative

One of the most ingenious applications of Internet telephony is C*NET (www.ckts.info/). C*NET stands for collectors' network, and in fact it's a global VoIP system for people who like telephones for their own sake. Yes, there are plenty of them, see www.thg.org.uk for proof!

The rather technical language of the C*NET website does not explain the system particularly well, but it is entirely free to use and has gateways into it from the public telephone system in most countries (see www.ckts.info/gates.php for a list and some test numbers you can call).

Users range from folk who simply enjoy the notion of being on a global hobbyist-run telephone network, to those who have preserved complete electromechanical telephone exchanges dating back seventy years or more. The directory at www.ckts.info/192/uk/ shows who is connected in the UK, and you'll note immediately that on C*NET you still use the old dialling codes without a 1 following the zero!

Users can choose any dialling code and number (as long as it's not already in use by another enthusiast) and quite a few people have arranged their C*NET number to have the same digits as their BT landline number. Some of the numbers connect to recordings, such as a gramophone recording from the 1930s of the dialling, ringing and engaged tones used seventy years ago and you can also check the time on the 'speaking clock' of the 1950s.

The equipment that people connect to C*NET is also interesting. Every piece of apparatus needs to be connected to a terminal adapter, but there are also converters for sale that enable old dial telephones to be used. You can also buy plug-in cards that convert redundant PCs into a telephone exchange that can handle pulse or tone-dialling telephones, with numbering ranges that you yourself choose.

Open-source 'Asterisk' software is used to programme these exchanges, and there are links to information pages at www.ckts.info/links.php. If you have a weakness for this kind of thing, you'll find the C*NET website really is a telephone techie's delight!



Charge Controller for 12V lead-acid or SLA batteries

Upgrade your standard 12V lead-acid battery charger or solar cell booster to a complete 2 or 3-step charger using this Charge Controller. It includes temperature compensation and LED indication. All parameters are adjustable for charging lead-acid or sealed lead-acid (SLA) batteries.

MOST lead-acid chargers are very basic, and simply pump current into the battery until it is switched off. The main problem with this type of charger is that ultimately it will overcharge the battery and may seriously damage it.

Adding a fully automatic Charge Controller to a basic charger will overcome these shortcomings. It will also prolong the life of your batteries and allow a battery to be left on a 'float' or 'trickle' charge, ready for use when required.

A typical lead-acid battery charger is shown in Fig.1. It comprises a mains transformer with a centre-tapped secondary output. The output is rectified using two power diodes to provide raw

DC for charging the battery. A thermal cutout opens if the transformer is delivering too much current.

On charge

Battery-charging indication may be as simple as a Zener diode, LED and resistor. The LED lights when the voltage exceeds the breakdown voltage of the Zener diode (12V) and the forward voltage of the green LED (at around 1.8V). Thus, the LED begins to glow at 13.8V and increases in brightness as the voltage rises. Some chargers may also have an ammeter to show the charging current.

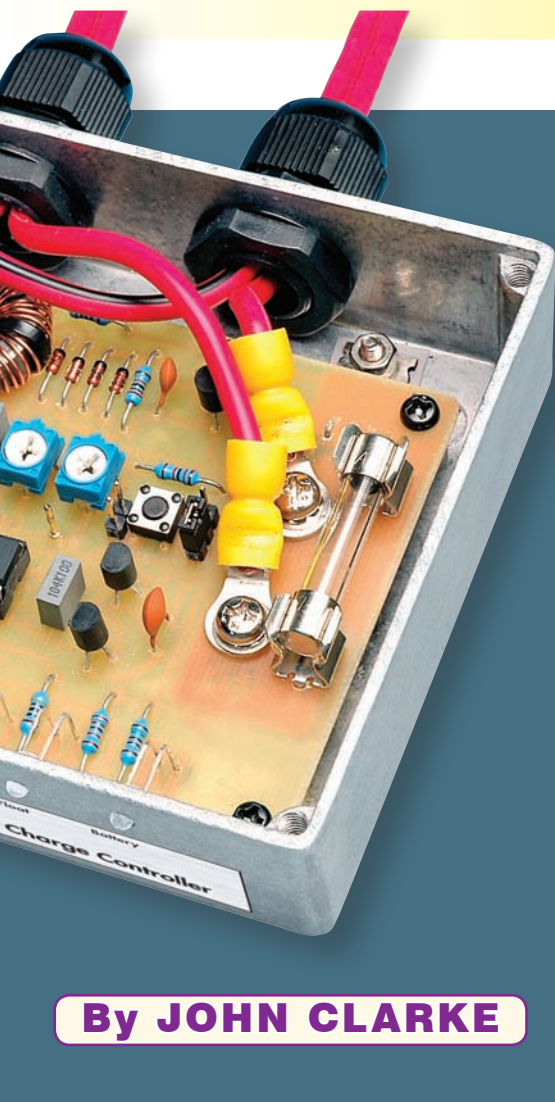
The charging current to the battery is provided in a series of high-

Main Features

- Suits 12V battery chargers up to 10A rating
- Lead-Acid and SLA charging
- Cyclic and float charging
- Optional absorption phase
- LED indication
- Fixed and adjustable parameters
- Temperature compensation

current pulses at 100Hz, as shown in Fig.2a.

The nominal 17V output from the charger will eventually charge a battery to over 16V if left connected long enough – this is sufficient to damage the battery. This is shown in Fig.2b, where the battery voltage required for full charge (called the 'cut-off voltage') is exceeded when left on charge for too long. By adding in the Charge Controller, we can do much better.



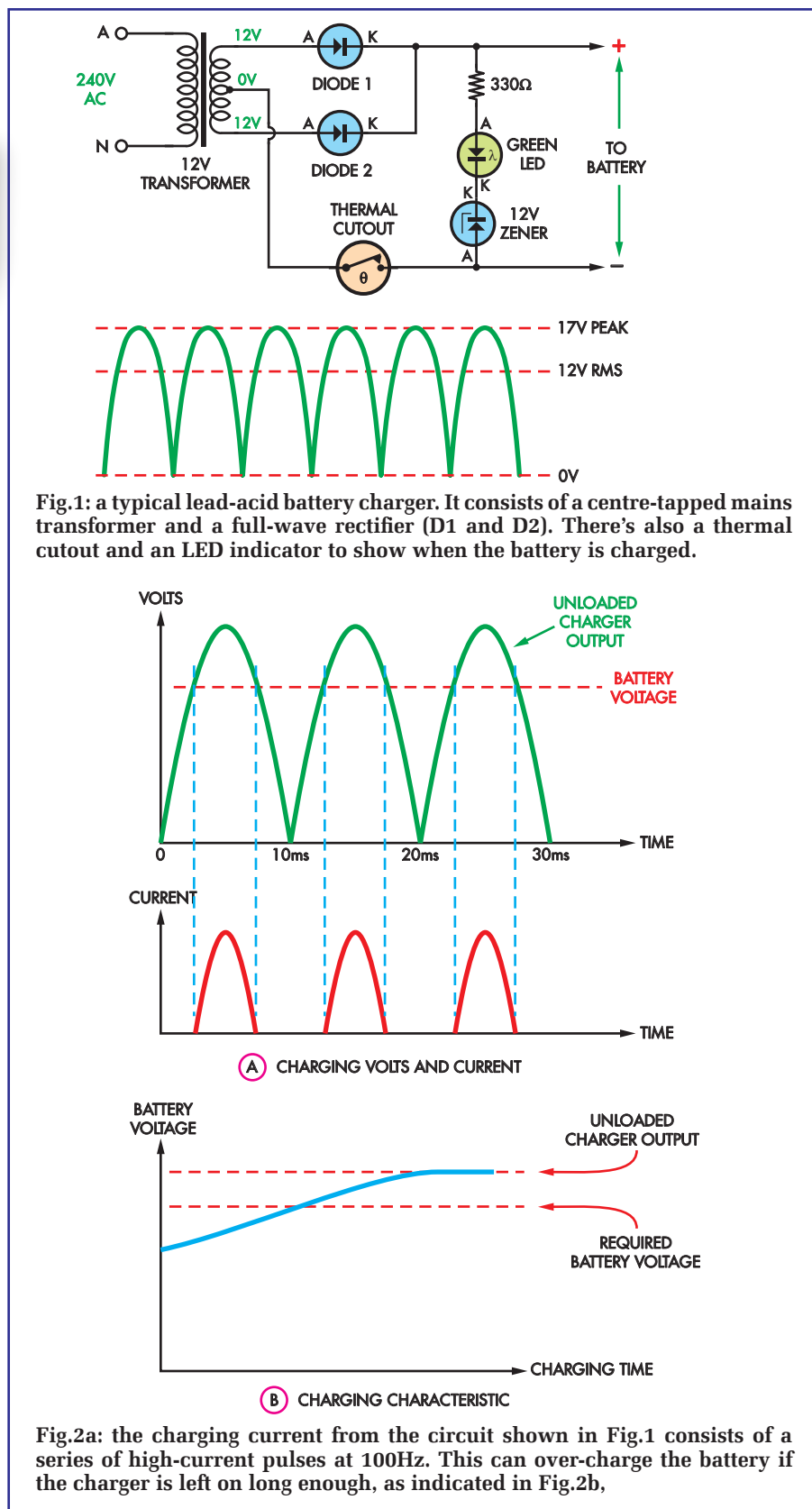
By JOHN CLARKE

Charge control

Fig.3 shows how the Charge Controller is connected in between the charger and the battery. The controller is housed in a compact diecast aluminium case. However, if your charger has plenty of room inside its case, the controller could be built into it.

In effect, the Charge Controller is a switching device that can connect and disconnect the charger to the battery. This allows it to take control over charging and to cease charging at the correct voltage. The various charging phases are shown in Fig.4.

The Charge Controller can switch the current on or off, or apply it in a series of bursts ranging from 20ms every two seconds through to continuously on. During the first phase, called 'bulk charge', current is normally applied continuously to charge as fast as possible. However, with low-capacity batteries, where the main charging current is too high, reducing the burst width will reduce the average current. So, for example, if you have a 4A battery charger, the current can be reduced



from 100% (4A) anywhere down to 1% (40mA) in 1% steps, using the charge rate control.

After the 'bulk charge' phase, the controller switches to the 'absorption'

phase. This maintains the cut-off voltage for an hour by adjusting the burst width and it brings the battery up to almost full charge. After that, the controller switches to 'float charge'.

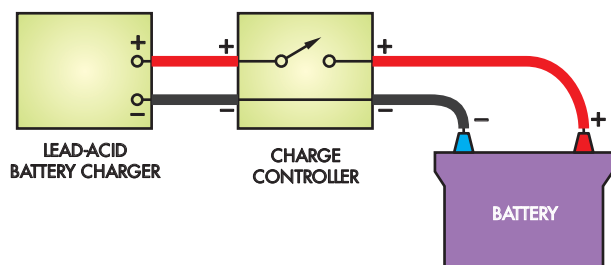


Fig.3: the Charge Controller is connected between the battery charger and the battery. This allows it to take control of charging and to cease charging at the correct voltage.

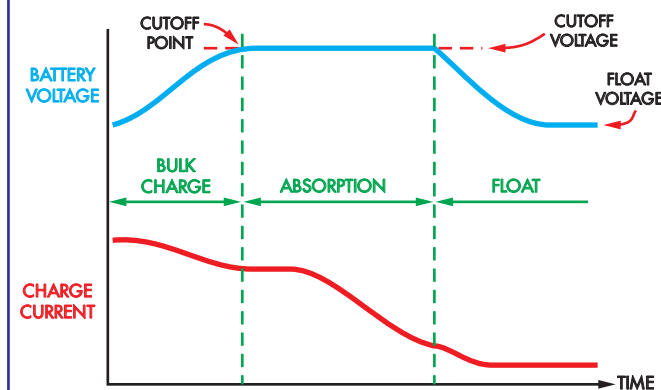


Fig.4: this diagram shows the three charging phases. It starts with a 'bulk' charge, then switches to the 'absorption' phase for an hour and then finally switches to 'float charge'.

This uses a lower cut-off voltage and a low charge rate.

If the charge rate control is set to less than 100%, the switch from absorption to float will occur when the burst width drops to 1% or after an hour, whichever comes first. The absorption phase is an option that can either be incorporated in everyday charging, or you can opt to just go to float charge after the bulk charge phase. When absorption is selected, this phase will be bypassed if the bulk charge takes less than an hour.

This bypassing prevents excessive absorption phase charging with an already fully charged battery.

Cut-off and float voltages

The actual cut-off and float voltages are dependent on the particular battery, its type and the operating temperature. For lead-acid batteries, typical cut-off and float voltages at 20°C are 14.4V and 13.8V, respectively. For sealed lead-acid (SLA) batteries, the voltages are lower at 14.1V and 13.5V, respectively.

These values are preset within the Charge Controller using the internal Lead-Acid/SLA jumper shunt. Alternative values are possible, and can be set manually from 0V to 16V in 48.8mV steps.

These voltage settings can be compensated for as temperature changes; as the temperature rises, the voltages should be reduced. Lead-acid batteries typically require $-20\text{mV}/^\circ\text{C}$ compensation, while SLA types typically require $-25\text{mV}/^\circ\text{C}$ compensation. These values can be set from 0 to $-50\text{mV}/^\circ\text{C}$ in 256 steps.

For our Charge Controller, temperature compensation is applied for temperatures between 0°C and 60°C. No charging is allowed at temperatures below 0°C. A negative temperature coefficient (NTC) thermistor inside the controller is used for temperature measurement. Four trimpots are used to make the various settings.

LED indicators

There are five LED indicators. LED1 (orange) flashes when the temperature is below 0°C, but otherwise does not light unless the thermistor connection is broken.

LED2 (red) indicates the 'bulk charge' phase, while LED3 (orange) and LED4 (green) are for the 'absorption' and 'float' phases. Note that there is an option for the Charge LED to indicate when charge is being applied to the battery during the absorption and float charge phases. If this is not required, it can be disabled so that

the Charge LED only lights during the bulk charge.

LED5 (green) indicates that a battery is connected, but is *not* an indication that charging is occurring.

Circuit description

The complete circuit diagram of the Charge Controller is shown in Fig.5. It uses a PIC16F88-I/P microcontroller (IC1) to monitor the battery voltage and adjust the switching of an N-channel MOSFET (Q1) to control the rate of charging.

Q1 connects in the positive supply line between the charger output and the battery. Gate drive for Q1 comes from a transformer-coupled supply that can typically provide 15V to the gate (G) when it is required to switch Q1 on.

The transformer-coupled gate drive arrangement allows us to use an extremely rugged, low-cost N-channel MOSFET rated at 169A, 55V and with a 5.3mΩ on-resistance.

To switch on Q1, IC1 delivers a 500kHz square-wave signal from its pin 9 (PWM) output to a complementary buffer stage using transistors Q2 and Q3. These drive the primary winding of toroidal transformer T1 via a 3.3nF capacitor.

The secondary windings of T1 step up the voltage by just over three times, and the resulting AC waveform is rectified by diodes D2 to D5, and then filtered with a 120pF capacitor. This process delivers a nominal 16V DC to Q1's gate via diode D6. This turns Q1 on to feed current to the external battery. Zener diode ZD2 is included to prevent the gate-to-source voltage of Q1 exceeding 18V.

Switch-off

While turning MOSFET Q1 on is fairly straightforward, turning it off is more involved because we want the switch-on and switch-off to be as fast as possible, to keep switching losses to a minimum.

Hence, to turn off Q1, the 500kHz signal from IC1 is switched off. With no signal at T1's secondary, the voltage across the 120pF capacitor is discharged via the 220kΩ resistor.

This discharge does not directly bring the gate of Q1 to 0V because it is isolated via diode D6. Instead, transistor Q4 discharges the gate capacitance of Q1, as its base is pulled low via the 220kΩ resistor. As a result, Q1 can be switched on in 56μs and off in 69μs.

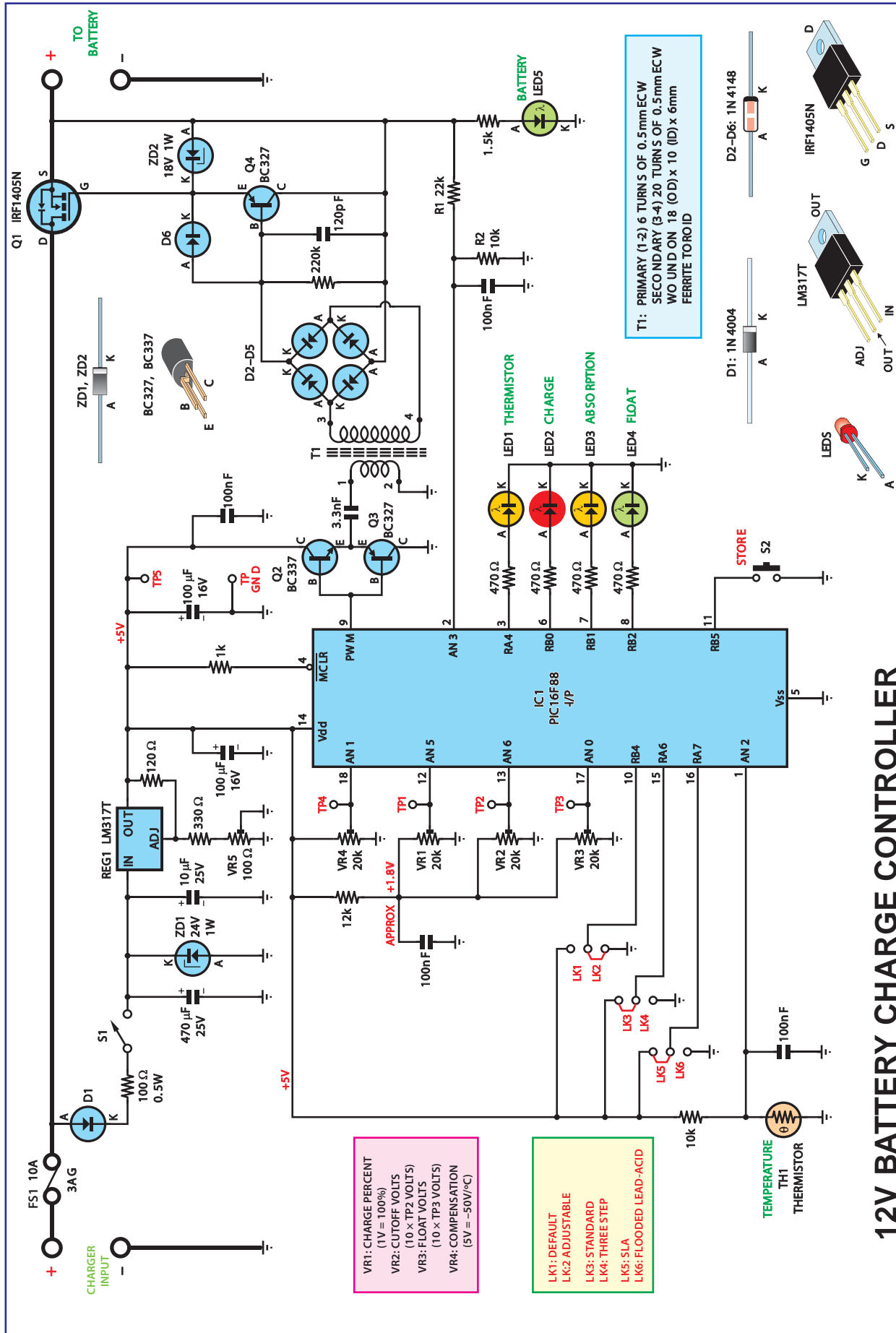
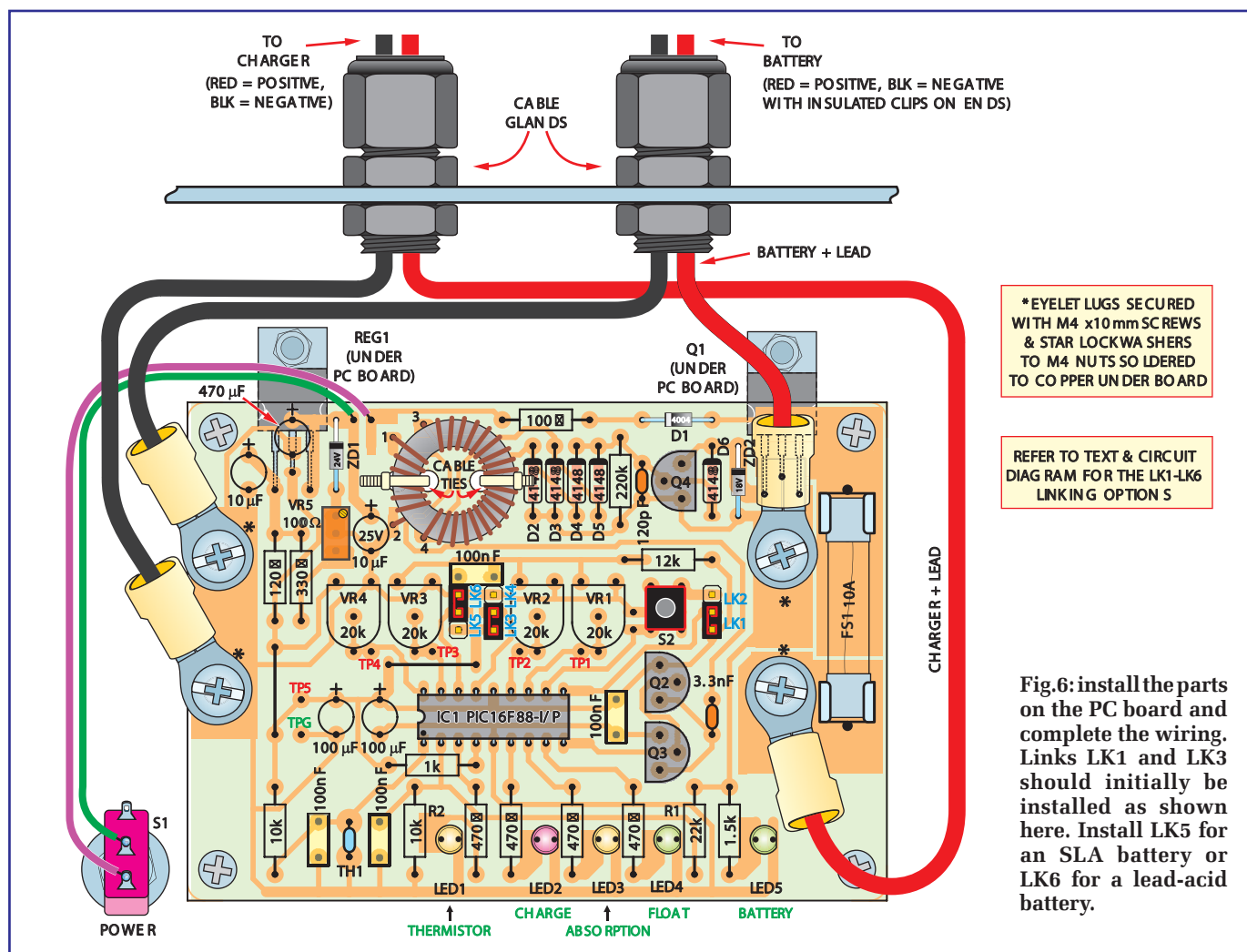


Fig.5: the circuit of the 12V Battery Charge Controller is based on a PIC16F88-I/P microcontroller (IC1). This monitors the battery voltage and pulse width modulates N-channel MOSFET Q1 to control the rate of charging. Pin 9 is the PWM output from the microcontroller and this drives Q1's gate via buffer stage Q2 and Q3, transformer T1, bridge rectifier D2-D5 and diode D6. Transistor Q4 turns the MOSFET off.



Power supply

Power for the circuit is obtained from the charger via diode D1, or it can come from the battery via the reverse diode within Q1. However, the latter is a spurious mode which has no useful function.

Diode D1 prevents reverse current to the controller circuit should the charger or battery be connected with incorrect polarity. The incoming supply from diode D1 and switch S1 is filtered using a 470 μ F 25V electrolytic

capacitor and fed to an adjustable voltage regulator (REG1) that is set to deliver a precise 5.0V. This feeds IC1 and buffer stage transistors Q2 and Q3.

IC1 monitors the battery voltage via a voltage divider comprising R1 and R2, and converts it to a 10-bit digital value via the AN3 input, pin 2. The signal is filtered with a 100nF capacitor to remove noise from the measurement. Furthermore, the battery voltage measurements are made after the 500kHz

signal from pin 9 is switched off.

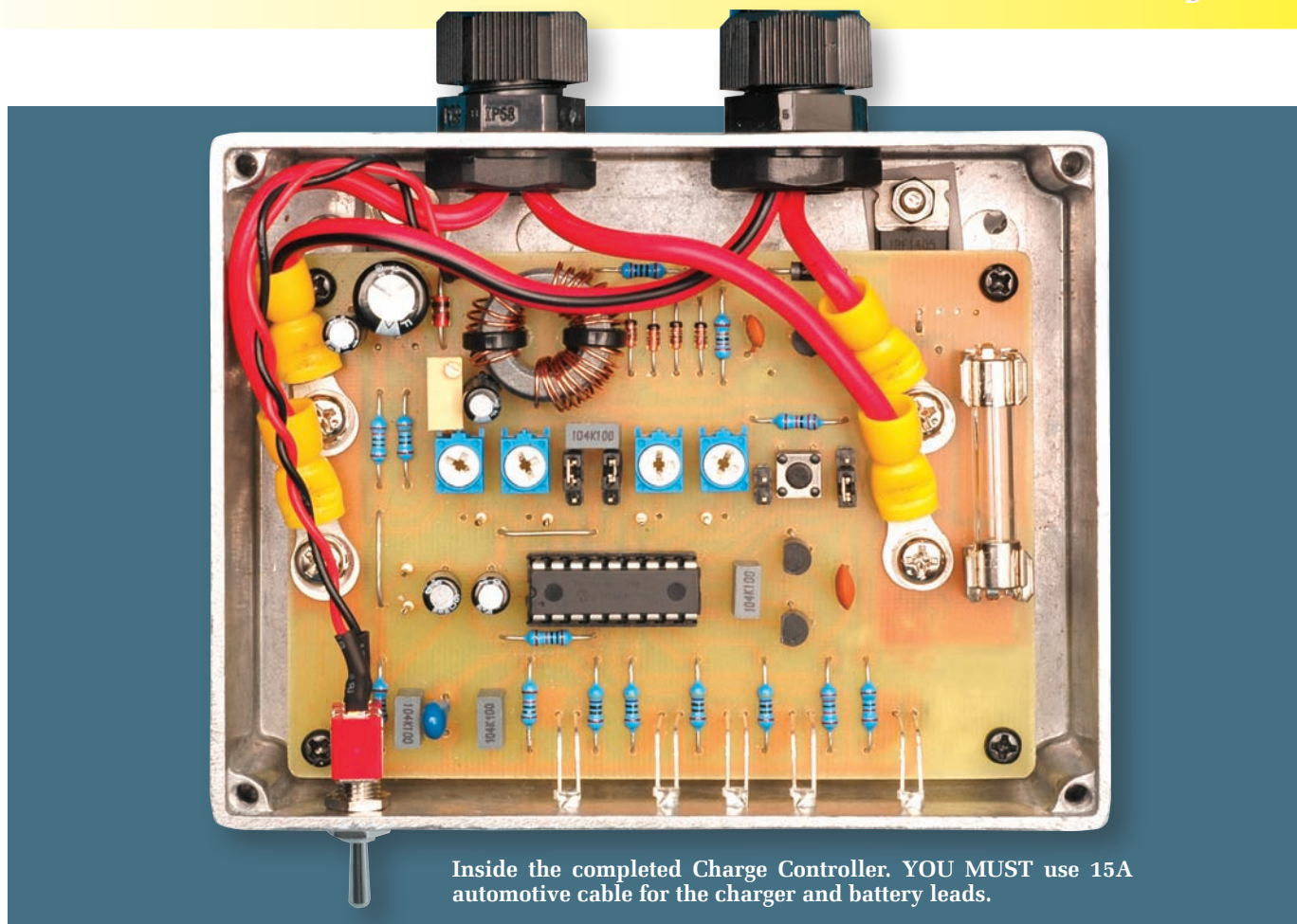
In addition, having Q1 switched off also prevents voltage fluctuations due to charging current in the leads to the battery 'under charge'.

Temperature measurement

As mentioned, an NTC thermistor (TH1) is used to measure temperature. It is connected in series with a 10k Ω resistor across the 5V supply. The resulting voltage across the thermistor is fed to IC1

Table 1: Resistor Colour Codes

<input type="checkbox"/>	No.	Value	4-Band Code (1%)	5-Band Code (1%)
<input type="checkbox"/>	1	220kΩ	red red yellow brown	red red black orange brown
<input type="checkbox"/>	1	22kΩ	red red orange brown	red red black red brown
<input type="checkbox"/>	1	12kΩ	brown red orange brown	brown red black red brown
<input type="checkbox"/>	2	10kΩ	brown black orange brown	brown black black red brown
<input type="checkbox"/>	1	1kΩ	brown black red brown	brown black black brown brown
<input type="checkbox"/>	4	470Ω	yellow violet brown brown	yellow violet black black brown
<input type="checkbox"/>	1	330Ω	orange orange brown brown	orange orange black black brown
<input type="checkbox"/>	1	100Ω	brown black brown brown	brown black black black brown



Inside the completed Charge Controller. YOU MUST use 15A automotive cable for the charger and battery leads.

AN2 input (pin 1) and converted to an 8-bit digital value. IC1 then computes the temperature with a look-up table. It can also sense whether the thermistor is disconnected (pin 1 at +5V) or shorted (pin 1 at 0V).

Analogue inputs AN5, AN6, AN0 and AN1 monitor the settings for charge rate percentage, cut-off voltage, float voltage and temperature compensation, as set by trimpots VR1-VR4.

Switch S2 stores the settings in IC1. S2 is normally open, and an internal pull-up resistor within IC1 holds the RB5 input (pin 11) at 5V.

When S2 is pressed, the pin 11 input of IC1 is pulled low (0V), this signals the program within IC1 to store the settings for VR2, VR3 and VR4 as the adjustable values for either SLA or lead-acid batteries. Where the values are stored depends on links LK5 and LK6, connected to the RA7 input at pin 16.

Link settings

If LK5 is in, pin 16 will be high (5V) and IC1 will store the settings as SLA parameters. If LK6 is in place, pin 16 will be low and the settings will be stored for the lead-acid parameters.

Links LK1 and LK2 determine whether the Charge Controller uses the

standard Default (LK1) or Adjustable setting referred to above.

Links LK3 and LK4 set the standard or three-step option. The standard charge selection switches charging to float charge directly after the main charge is complete.

The three-step selection will run the absorption phase after the main charge, provided that the full charging process takes more than one hour. For a main charge of less than one hour, the charging will switch directly to float charge.

Note that these link combinations cannot be used together you must use one or the other. For example, you can use LK1 or LK2, LK3 or LK4, and LK5 or LK6.

Software

The software files are available via the *EPE* Library site, accessed via www.epemag.com. Pre-programmed PICs will also be available from Magenta Electronics – see their advert in this issue for contact details.

Construction

The Charge Controller is built using a PC board, code 741, measuring 102mm × 72mm. This board is available from the *EPE PCB Service*. The PCB is

housed in a diecast box measuring 118 × 93 × 35mm.

Start construction by checking the PC board for any defects such as shorted copper tracks, breaks in the copper areas and for correct sizes for each hole. The holes for the four-corner mounting screws and the toroidal transformer cable tie mounts need to be 3mm diameter, while the four mounting points for the crimp eyelets need to be 4mm diameter.

Check also that the PC board is cut and shaped to size so that it fits into the box.

That done, the first step is to secure the four M4 nuts to the underside of the PC board in the four eyelet mounting positions using M4 screws. Preheat each nut with a soldering iron and solder it to the PC board. When cool, the screws can be removed.

Construction can now be continued by installing the two wire links and the resistors. Take care to place each resistor in its correct position. A colour code table is provided as a guide to finding each value, but use your DMM (digital multimeter) to check each resistor before inserting it into the PC board.

Next, install the PC stakes for the test points TP GND and TP1 to TP5. Install the 2-way header for switch

Shortcomings of the Charge Controller

To round out our description of this project, we should also mention its possible shortcomings. In most cases these will not be a problem, but in special charging applications they could be significant.

1) Pulsed operation

The pulsed current can cause extra heating within the battery because losses and therefore heat build up are related to the square of the current. So, for example, to develop a 1A charge current from a 4A charger, the duty cycle may be set to 25% so that there is 4A pulsed for 25% of the time. This averages to 1A. However, by pulsing at 4A and 25% duty cycle, the current squared value is 16. When multiplied by the 25% duty cycle, the average current squared value reduces to 4. So the power losses and heating within the battery are four times greater compared to a charger that produces a continuous 1A.

2) Absorption and float charge

Because we pulse the charge current, the battery voltage fluctuates and rises with the current pulse and falls when the pulse is off. We measure the voltage just after the charge pulse is switched off. Compared to a charger that has a continuous lower current, the battery voltage may be maintained at a different value.

3) Charging indication

Due to the battery supplying the circuit power supply via the reverse diode in Q1, it can appear that charging is taking place even when the charger is not connected. It is important to check that the charger is connected and is switched on.

4) Battery discharge

If the charger is switched off with the battery connected, then the battery will eventually discharge due to the 30mA load of the Charge Controller.

is close to the battery and the metal box will not normally heat up. As a consequence, its temperature should be similar to the battery temperature if we ignore heat rise due to charge current within the battery.

If the thermistor is to be mounted externally, then wires can be connected where the thermistor mounts on the PCB, and passed through a cable gland in the box. Alternatively, use a 3.5mm jack socket and plug. For external use, the thermistor can be covered in heat-shrink tubing and attached to the side of the battery using Velcro or similar tape.

The capacitors can be installed next. Note that the electrolytic types must be oriented with the polarity shown. Install transistors Q2 to Q4 and trimpots VR1 to VR5, then install switch S2.

Fuse FS1 comprises two fuse-clips and the fuse. The fuse clips must be oriented so that the end stops are facing outwards, so that the fuse can be clipped into place – see Fig.6 and photos.

Mounting the LEDs

The LEDs are mounted at right angles to the PC board. Bend the leads 12mm back from the front lens of each LED, taking care to have the anode (a) (longer lead) to the left and then bend the leads downward. The LEDs then insert into the PC board and sit 8mm above the top of the board – see Fig.7.

Voltage regulator REG1 and MOSFET Q1 mount under the PC board with their leads bent up at right angles, as shown in Fig.7. They are placed so that the metal face sits at the same depth below the bottom face of the PC board as the spacers (at 9mm).

Transformer

Transformer T1 is made up using a ferrite ring-core toroid and some 0.5mm enamelled copper wire. There are two separate windings. Wind on the primary with six turns and the secondary with 20 turns. The winding direction is not important. The wire ends can be passed through the holes in the PC board, taking care to place the six-turn winding wire ends in the '1' and '2' holes and the 20-turn winding in the '3' and '4' holes.

The enamel insulation on the wire ends can be stripped away using a hobby knife, and the leads soldered to the PC board. Cut off excess wire, then secure the T1 assembly using two cable ties, which pass through the PC board as shown.

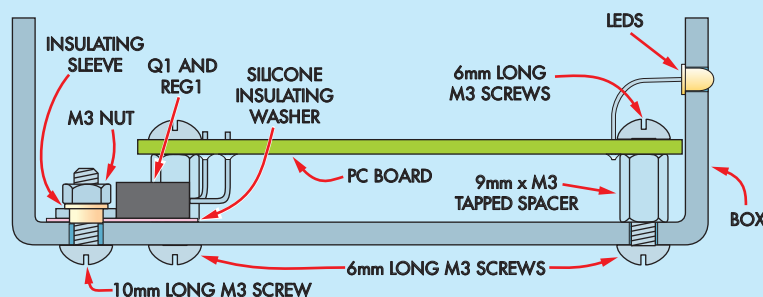


Fig.7 (above): here's how the PC board is mounted in the case. Note that the metal tabs of Q1 and REG1 must be isolated from the case using insulating washers and bushes (see text).

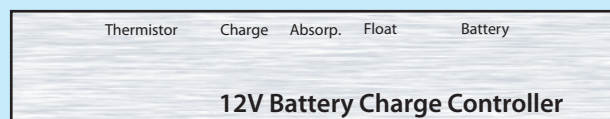


Fig.8: this is the full-size front panel artwork for the specified case.

S1 and the 3-way headers for link LK1 to LK6.

Now install the diodes and the Zener diodes, with the orientation as shown. IC1's socket can then be mounted, and this must also be oriented correctly. Note that IC1 is not inserted in its socket

until certain voltage checks have been carried out at the testing stage.

Thermistor mounting

Normally, the NTC thermistor (TH1) can be mounted directly on the PC board because the Charge Controller

Casing up

Work can now commence on the metal box. First, position the PC board in the box with the edge closest to the LEDs sitting 3mm away from the edge of the box. Mark out the four corner mounting hole positions, then drill (and deburr) these holes to 3mm and mount the four 9mm stand-offs.

Now mount the PC board in position and secure it using M3 x 6mm screws. Mark out the mounting holes for Q1 and REG1, and mark out the LED and S1 positions. Also mark out the two holes for the cable glands. That done, remove the PC board and drill out the holes. Be sure to deburr, especially the two holes for Q1 and REG1.

The PC board can now be mounted inside the box. Isolate the tabs of Q1 and REG1 from the case, using insulating washers and mounting bushes – see Fig.5 and Fig.7. Now check that the tabs for REG1 and Q1 are insulated from the metal box by measuring the resistance with a multimeter. The reading should be high; above 1MΩ. **The box is totally isolated from the electrical connections so that accidental contact of the box to a battery terminal will not cause a short circuit.**

Install the two cable glands and pass the figure-8 cable through them, ready to attach the crimp eyelets. We used the striped wire as the negative and the plain red wire as the positive.

Connect the crimp eyelets using a crimping tool and secure them to the PC board using the M4 screws and star washers. Make sure the eyelets are not shorting to adjacent parts, especially the fuseholder. The battery leads will need the large insulated clips connected to the end – use red for positive and black for negative.

The Charge Controller leads can simply be bared at their ends and connected to the charger clips or they can be permanently wired to the charger.

Switch S1 can now be wired to the PC stakes on the PC board and covered with heatshrink tubing. Finally, fit the stick-on rubber feet to the underside of the box.

Testing

Install links LK1, LK3 and either LK5 (SLA) or LK6 (lead-acid). Do not place a link onto the 2-way header adjacent to S2, as this is for an optional front panel-mounting switch for S2.

Specifications

Under-voltage burst charge: 10.5V (inoperative if the selected cut-off voltage is below 12V).

Under-voltage burst rate: approx. 200ms burst every 2s with charge rate set to 100%. Burst width is reduced with a lower charge rate. Charge, Absorption and Float LEDs all flash. Battery LED flashes with no battery and charger connected. The LED lights continuously when battery connected.

Under temperature: 0°C; no charge; thermistor LED flashes on and off at 1s rate.

Temperature measurement resolution: 0-60°C in 1°C steps.

Thermistor out: Thermistor LED fully lit; no charge.

Compensation: 0°C to 60°C

Adjustable compensation: 0-50mV/°C in 256 steps (separate SLA and lead-acid battery adjustments)

Adjustable cut-off and float voltage: 0-16V in 48.8mV steps. Separate SLA and lead-acid battery adjustments

Fixed value: SLA cut-off 14.1V, float 13.5V and -25mV/°C compensation with respect to 20°C. Lead-acid 14.4V, 13.8V and -20mV

Charge rate: adjustable from 100% to 0% in 1% steps. Pulses are adjusted in approximately 20ms steps.

PWM drive signal: 500kHz.

MOSFET gate rise-time for an on pulse: 56μs (10-90%) for a 16V gate voltage

MOSFET gate fall time for an off pulse: 69μs

LEDs

Bulk Charge: Charge LED flashes at a duty that equals the % charge rate.

Absorption: Absorption LED lit (optional Charge LED shows whenever charge is on to maintain battery voltage).

Float: Float LED lit (optional Charge LED indication).

Charging

Charge: charges at the charge rate (%) until the cut-off voltage is reached.

Absorption: adjusts current pulse duty cycle to maintain cut-off voltage.

Float: adjusts current pulse duty to maintain float voltage.

Float and absorption current control

Charge duty cycle is reduced fast (15% every 2s) if the battery voltage is above the required value by more than 0.25V, and reduced by 1% every 2s if the battery voltage is above the required value by up to 0.25V. Conversely, charge duty cycle is increased fast (3% per 2s) if the battery voltage is less than 0.25V below the required value and increased at a slow rate (1% per 2s) if the battery voltage is no more than 0.25V below the required voltage.

Now connect a multimeter, set to read 5V DC, between 'test points' TP GND and TP5. Connect a supply to the charger input and adjust VR5 for a 5.0V reading on the multimeter. Check that the voltage between pin 5 and pin 14 pin on IC1's socket is also 5V. If so, switch off power and insert IC1, taking care to orient it correctly.

Charging

For most large batteries you would set the charge rate to 100%. In this case, simply set VR1 fully clockwise. You can use the 100% setting for all batteries that can accept the charge rate from your charger. Most batteries can accept up to 30% of the quoted Ah capacity as a current. So a 100Ah battery can accept 30A.

If your charger supplies less than 30A, then the 100% setting can be used. If your battery is rated in RC (reserve capacity) you will need to convert to Ah.

Reserve capacity is a specification in minutes, and specifies how many minutes a fully-charged battery can deliver 25A before the voltage drops to 10.5V. A battery with an RC of 90 will supply 25A for 90 minutes. The amp-hour specification (Ah) refers to the current that can be supplied (usually over a 20 hour period). So a 100Ah battery can supply 5A for 20 hours.

To convert from RC to Ah, multiply the RC value by 0.42 (derived by multiplying by 25A to get the capacity in Amp minutes and dividing by

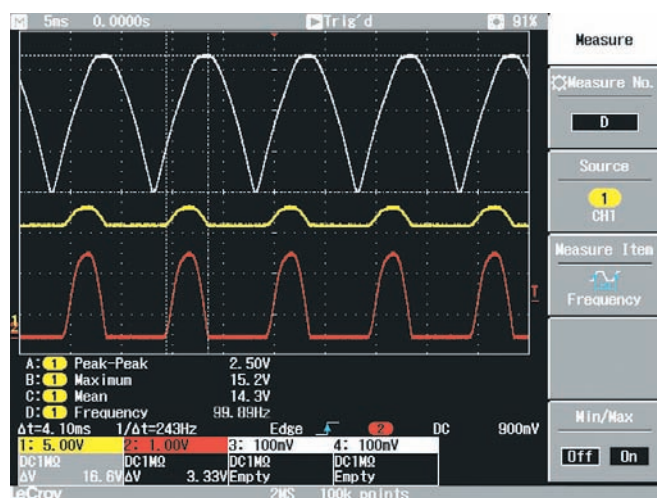


Fig.9: this scope shot duplicates the waveforms shown in Fig.2a. The white trace is the charger input, while the red trace shows the 100Hz current pulses into the battery.



Fig.10: this shot shows the Charge Controller operation. The red trace is the 100Hz input from the charger, while the yellow trace shows the current into the battery.

60 to convert from minutes to hours). In practice, because the RC capacity specification uses 25A, the conversion from RC to Ah often gives a lower Ah value than the battery's actual Ah capacity. This is because the Ah capacity often requires much less current from the battery over a longer period.

For batteries that require a lower current than that supplied by the charger, the charge rate can be reduced from 100%. So, for a charger that is rated at 4A and a battery that can only accept a 2A charge current, set the charge rate to 50%.

The charge rate is set using VR1, where the voltage at test point TP1

represents the percentage. Voltages of 1V or more give 100%, while values below 1V provide lower percentage charge rates. For example, a 0.5V reading gives a 50% charge rate duty cycle.

Note that when charging a battery that has less than 10.5V across its terminals, the charging will be in a specific burst mode, with the burst at 200ms every two seconds when the charge rate is set to 100%. At lower charge rates, the burst length will be reduced accordingly. During under-voltage burst, the Charge, Absorption and Float LEDs flash.

As mentioned earlier, the charge LED can be set to flash when charge is applied during the absorption and float phases. This is the initial setting.

If you do not require the charge LED to show during these phases, you can disable this. Switching off power and pressing S2 while the power is re-applied will disable this feature. The change is acknowledged by a minimum of two fast (two/second) flashes of the Charge LED. The acknowledgement flashing continues until the switch is released.

You can re-enable the feature by pressing S2 at power up again.

Setting the parameters

Most battery manufacturers will specify the required cut-off (also called the cyclic voltage), the float (also called the trickle voltage) and the temperature compensation for each battery. Note that the cut-off and float voltages must be the values for 20°C.

The temperature compensation required by manufacturers is usually shown as a graph of voltage versus temperature. You need to convert this to mV/°C. To do this, take the difference between the voltages at two different temperatures and divide by the temperature difference.

For example, a battery graph may show the cut-off or cyclic voltage at 0°C to be 14.9V. At 40°C it may be 14.2V. So $(14.2 - 14.9)/40$ is -17.5mV/°C .

Where the float temperature compensation is different to the cyclic temperature compensation, a compromise between the two values will have to be made. Note that the graph can be interpreted over a smaller temperature range that is consistent with the temperatures under which you expect to be using the charger.

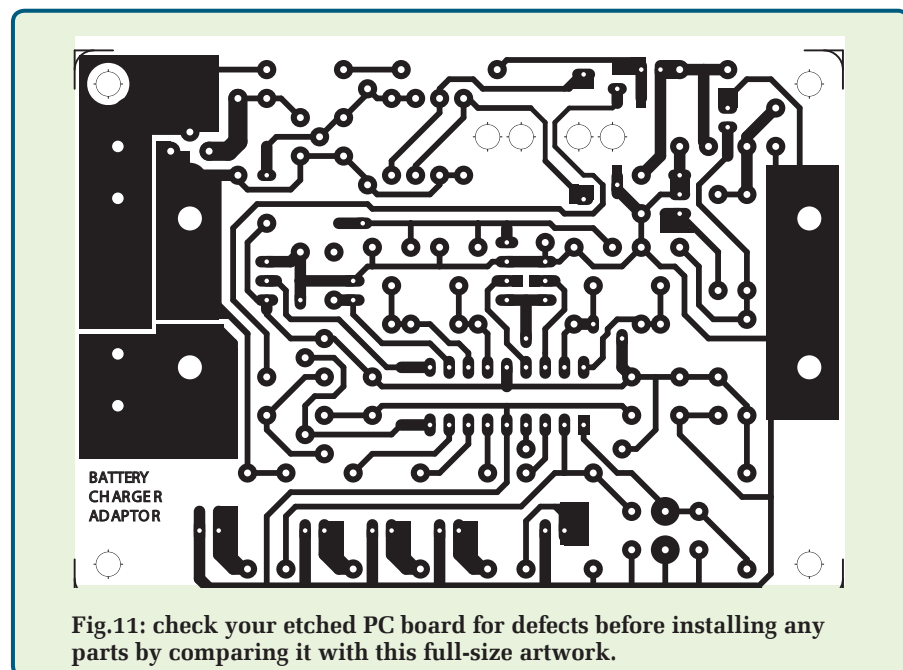


Fig.11: check your etched PC board for defects before installing any parts by comparing it with this full-size artwork.

Parts List – Charge Controller

1 PC board, code 741, available from the *EPE PCB Service*, size, 102 × 72mm
1 diecast box, 118 × 93 × 35mm
1 SPDT toggle switch (S1)
1 SPST micro tactile switch, with 0.7mm actuator (S2)
2 cable glands for 4-8mm diameter cable
2 TO-220 silicone insulating washers and mounting bushes
4 small adhesive rubber feet
2 PC-mount fuse clips
1 10A fuse (FS1)
1 ferrite ring-core, 18 × 10 × 6mm (Jaycar LO-1230 or equivalent) (T1)
1 NTC thermistor (10kΩ at 25°C) (TH1)
1 18-pin IC socket
4 9mm long M3 tapped spacers
8 M3 × 6mm screws
2 M3 × 10mm screws
2 M3 nuts
4 M3 × 10 screws
4 M4 nuts
4 M4 star washers
4 insulated crimp eyelets

2 100mm cable ties
1 1m length of 15A figure-8 automotive cable
1 100mm length of medium-duty red hook-up wire
1 100mm length of medium-duty black hook-up wire
3 3-way headers with 2.54mm spacing
1 2-way header with 2.54mm spacings
3 jumper plugs
8 PC stakes
2 insulated battery clips (red and black)
1 600mm length of 0.5mm enamelled copper wire
1 50mm length of 0.7mm tinned copper wire

Semiconductors

1 PIC16F88-I/P microcontroller, pre-programmed – see text (IC1)
1 IRF1405 *N*-channel MOSFET (Q1)
1 BC337 *NPN* transistor (Q2)
2 BC327 *PNP* transistors (Q3, Q4)

1 24V 1W Zener diode (ZD1)
1 18V 1W Zener diode (ZD2)
1 1N4004 1A diode (D1)
5 1N4148 diodes (D2 to D6)
1 LM317T adjustable voltage regulator (REG1)
2 orange 3mm LEDs (LED1 and 3)
1 red 3mm LED (LED2)
2 green 3mm LEDs (LED 4 and 5)

Capacitors

1 470μF 25V PC radial elect.
2 100μF 16V PC radial elect.
1 10μF 25V PC radial elect.
4 100nF MKT polyester
1 3.3nF ceramic
1 120pF ceramic

Resistors (0.25W, 1% metal film)

1 220kΩ 4 470Ω
1 22kΩ 1 330Ω
1 12kΩ 1 120Ω
2 10kΩ 1 100Ω 1/2W
1 1kΩ

Trimpots

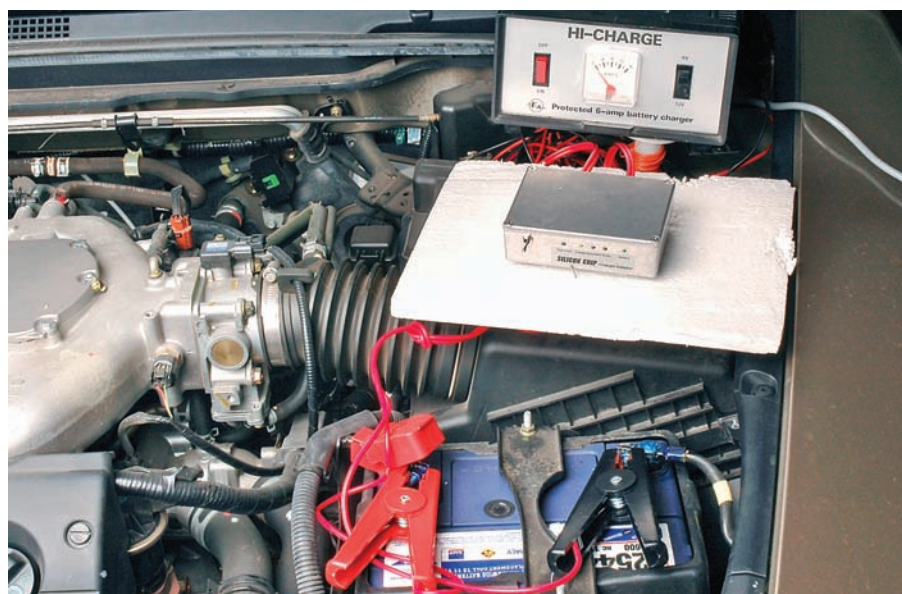
4 20kΩ horizontal mount trimpots (VR1-VR4)
1 100Ω multiturn top adjust trimpot VR5)

To set the adjustable parameters, apply power to the Charge Controller via a battery or charger and select the battery type with link LK5 or LK6. That done, connect a multimeter between TP GND and TP2 and adjust the required cut-off voltage using trimpot VR2.

Each volt represents a 10V cut-off, so 1V at TP2 sets a 10V cut-off, 1.44V sets a 14.4V cut-off, and so on. Now connect the multimeter to TP3 and adjust VR3 for the required float voltage. Each volt at TP3 represents 10V float.

For the temperature compensation, monitor TP4 and adjust VR4 for the required compensation. Here, 5V represents -50mV/°C and 2V represents -20mV/°C. Press switch S2 to store the values. The Thermistor, Charge and Float LEDs will all flash twice to acknowledge the setting and that the cut-off, float and compensation values have been stored.

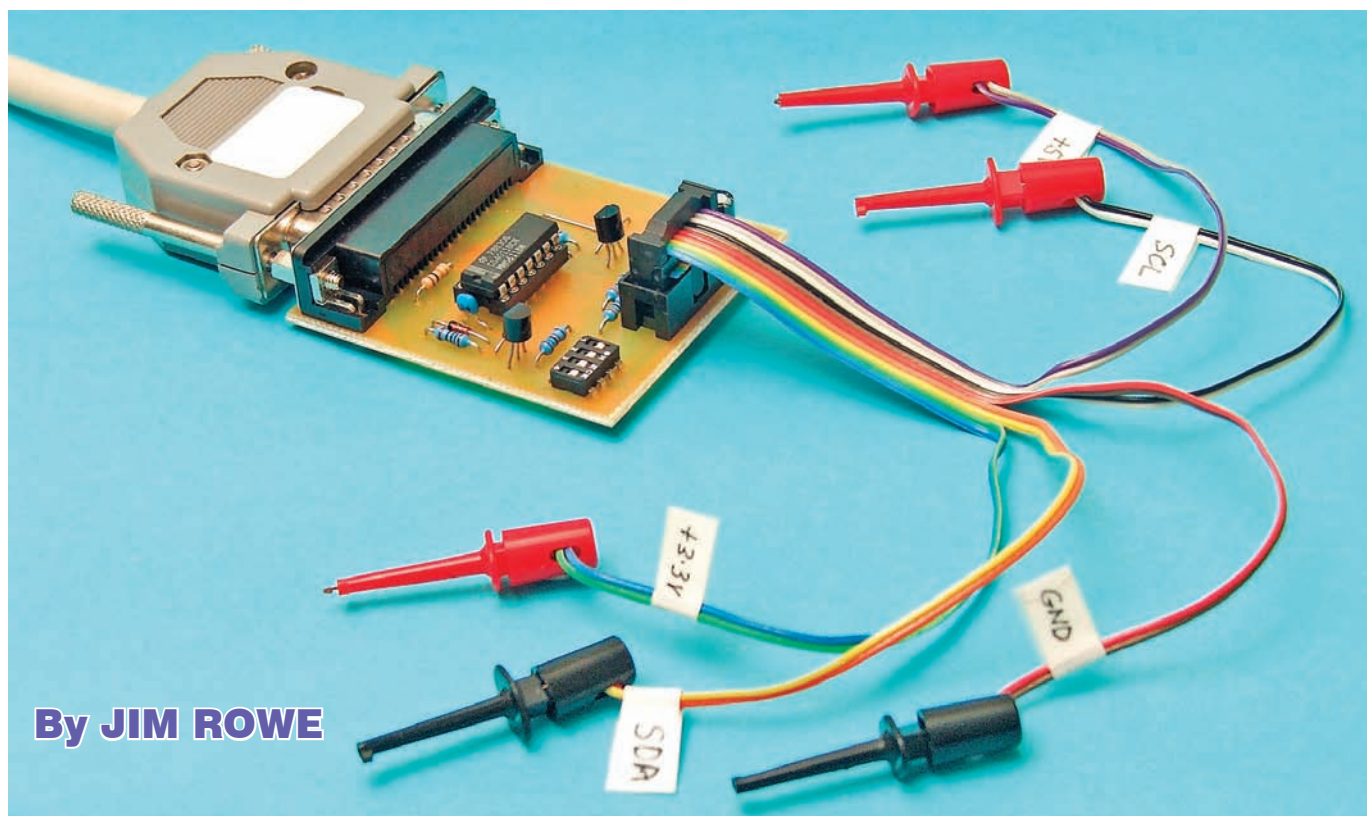
You can store the parameters for the second battery type by changing the settings for links LK5 and LK6, and



You will need to fit a couple of heavy-duty clips to make the connections to the battery. And yes, you can use it to charge your car's battery.

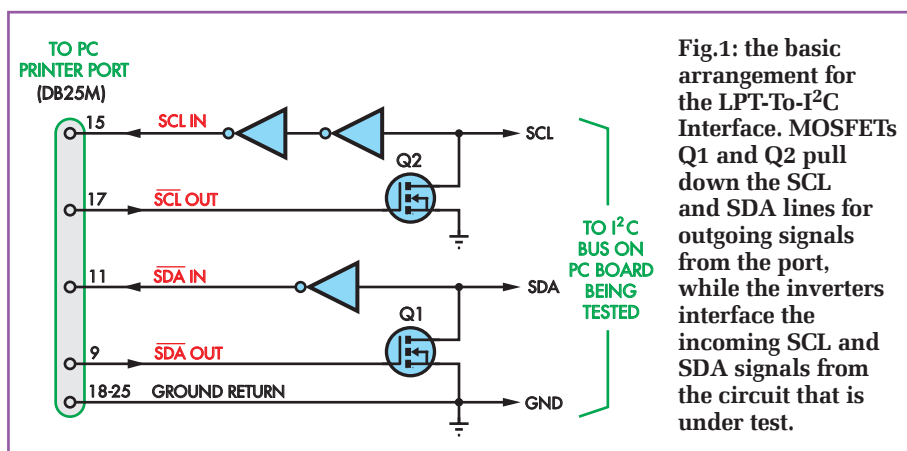
readjusting the trimpots. Store the values using switch S2. Note that adjusting the trimpots without pressing the store switch will not store new values. *EPE*

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A low-cost LPT-to-I²C interface for debugging

Tracking down problems in circuits which are programmed via an I²C bus can be tricky and time-consuming, unless you take advantage of a debugging program running on a PC. Here's a low-cost, easy-to-build printer port to I²C interface designed to work with the Philips/NXP debugging program URD312.exe.



JUST recently, I was trying to finish a project that uses a couple of video-processing ICs that are programmed via the I²C bus. However, I struck trouble with one chip. For some reason, it wasn't responding correctly to the set-up data I was sending to it from the project's microcontroller, despite going through my control program umpteen times searching for bugs (or programming errors).

Even when I wrote a test program and captured the I²C bus activity with my digital scope, I still couldn't track down the source of the trouble.

Helpful NXP

Fortunately, before tearing out the last few strands of my hair, I decided to seek help from the support people at NXP (formerly Philips Semiconductors) – not only because the chip concerned happened to be one of theirs, but also because it was Philips that developed I²C in the first place. After all, if anyone should be expert at solving I²C problems, it should be NXP.

As it turned out, they were very helpful. An NXP support engineer promptly sent me an email suggesting several things to try. Then, when that didn't fix things, he suggested I try analysing the problem using a debugging program running on a PC. Not only that, but he also sent me a copy of the latest version of their free I²C debugging program (called 'URD'), which they developed quite a few years ago. The current version turned out to be v3.12, which comes as a self-installing package called **URD312.exe** (more on this later).

Along with the program, he also sent a device data register set-up file for the video processing chip I was working with, so the URD program could communicate with it sooner. And last but by no means least, he sent me a PDF file with the circuit of the original PC printer port/I²C interface card that the URD program was designed to work with, so I could build one up for the troubleshooting.

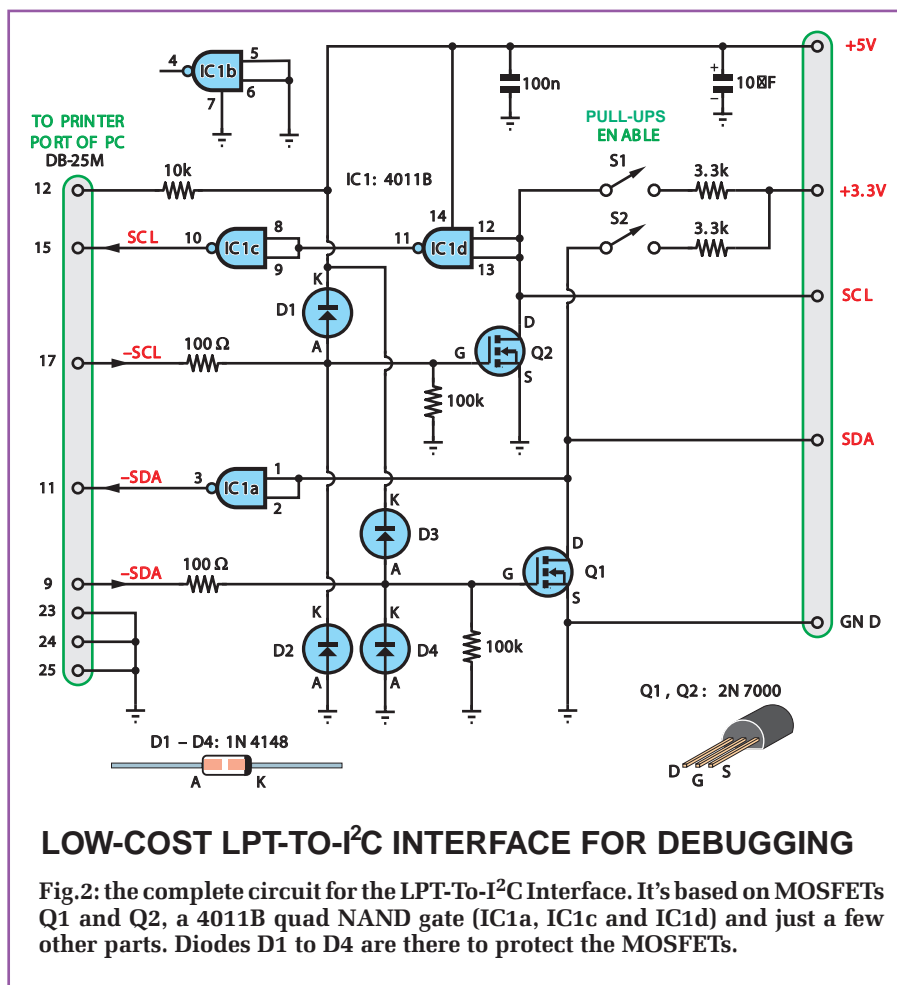
That's pretty good support, don't you think?

As it happened, the original interface used a 74LS05 chip that I didn't have, so I decided to update the circuit to use devices that are readily available nowadays. And that's the project described here – it uses a 4011B quad NAND gate, a couple of MOSFETs and not much else.

How it works

Like the original NXP/Philips interface, this unit is designed to allow the URD program to communicate with an I²C bus on a development board via the PC's parallel printer port (LPT). The basic arrangement of the circuit is shown in Fig.1.

In operation, the URD program sends out the SCL pulses in inverted form via pin 17 of the printer port (originally used for the SEL). So the interface uses this printer port line to control MOSFET Q2, which is used to pull down the SCL line of the I²C bus.



LOW-COST LPT-TO-I²C INTERFACE FOR DEBUGGING

Fig. 2: the complete circuit for the LPT-To- I^2C Interface. It's based on MOSFETs Q1 and Q2, a 4011B quad NAND gate (IC1a, IC1c and IC1d) and just a few other parts. Diodes D1 to D4 are there to protect the MOSFETs.

Conversely, the URD program monitors the I²C bus SCL pulses via pin 15 of the printer port, which was originally used for monitoring the printer's Error. As a result, the interface feeds back the SCL line status to pin 15 via a pair of inverters, which function as a non-inverting buffer.

Similarly, the URD program sends out data to the SDA line (in inverted form) via pin 9 of the printer port, originally used to send parallel data bit 7 to the printer. The interface uses this printer port line to control MOSFET Q1, which is used to pull down the SDA line of the I²C bus.

Finally, the URD program receives data from the SDA line (again in inverted form) via pin 11 of the printer port, which was originally used for monitoring the printer's Busy/Ready. So, in the interface, we feed the SDA line data back to pin 11 via a single inverter.

So that's the basic idea of the way the interface works. Let's now take a look at the full circuit for the LPT-To-I²C Interface, which is shown in Fig.2.

Circuit details

As shown in Fig.2, two low-cost 2N7000 *N*-channel MOSFETs (Q1 and Q2) are used as the SCL and SDA pull-down transistors. Inverter stages IC1c and IC1d (part of a 4011B quad CMOS NAND gate) are used for interfacing the SCL line, while IC1a is used to interface the SDA line. The fourth gate (IC1b) is unused.

Most of the rest of the circuitry is used to protect MOSFETs Q1 and Q2 from possible damage due to electrostatic charge build-up on the printer port lines when the interface is not connected to a PC. That's the reason for the 100kΩ resistors connected from each MOSFET gate (G) to ground (0V), and for diodes D1 to D4. The latter prevent each gate from being taken more negative than ground or more positive than the +5V rail, which is used to power IC1.

The $10\mu\text{F}$ capacitor on the +5V line provides supply line filtering, while the $10\text{k}\Omega$ resistor ensures that pin 12 of the printer port is pulled high. This is a

Constructional Project

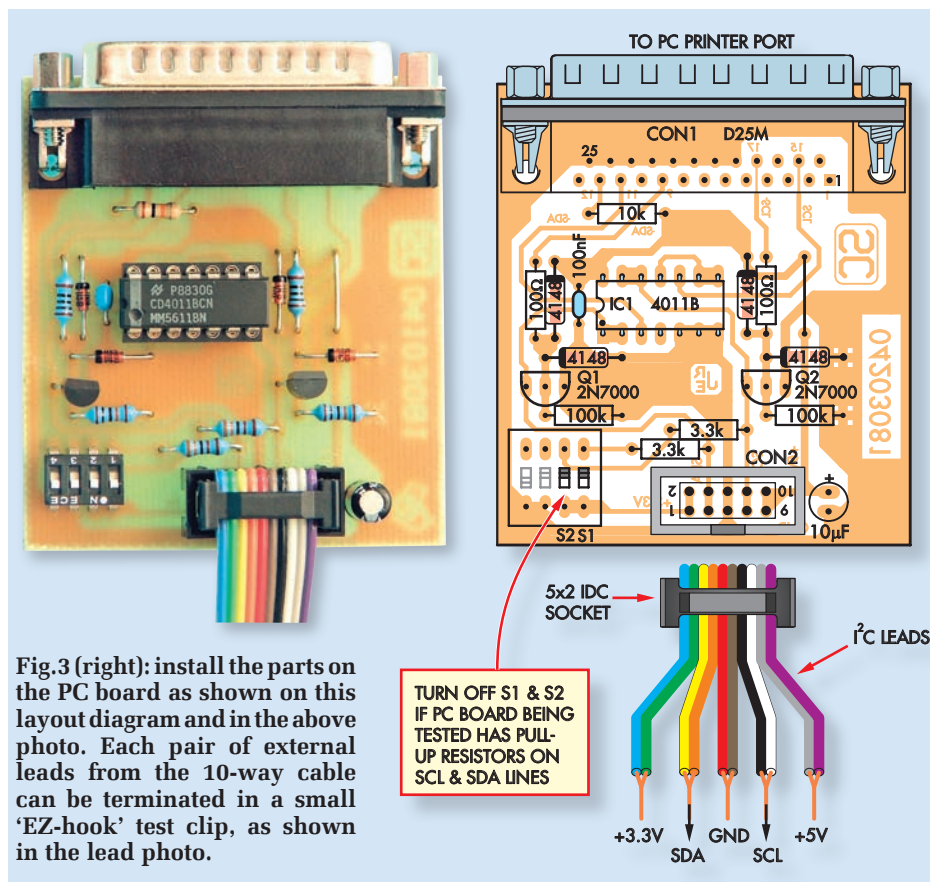


Fig.3 (right): install the parts on the PC board as shown on this layout diagram and in the above photo. Each pair of external leads from the 10-way cable can be terminated in a small 'EZ-hook' test clip, as shown in the lead photo.

requirement of the URD program, which expects to find a logic high on this pin of the printer port (originally used for monitoring the 'Out of paper' line).

Switches S1 and S2 can be used to switch in two 3.3k Ω pull-up resistors on the SCL and SDA lines respectively. This is necessary if the I²C bus lines on the PC board being tested don't already have pull-up resistors.

Note that the interface line marked '+3.3V' must be connected to the +3.3V line supplying power to the I²C chips on the board being tested, so the interface pull-ups can function correctly.

As indicated, the interface pull-ups aren't needed if the board being tested is already provided with pull-ups of its own. In that case, S1 and S2 are simply left open (and the interface's +3.3V lead doesn't need to be connected to anything).

Building it

Building the interface is very straightforward, as all the parts are mounted on a small PC board measuring just 55mm \times 61mm. This board is available from the *EPE PCB Service*, code 744. These parts include the male D25 connector used to mate with the PC printer port.

Fig.3 shows the component layout. Install the single wire link first, then mount the resistors. Check the resistor values with a multimeter, before mounting them on the PCB. The four diodes and the two capacitors are next. Be sure to orientate the diodes and the 10 μ F electrolytic capacitor exactly as shown.

Follow these parts with the two MOSFETs (Q1 and Q2) and the IC, again taking care to ensure they go in the right way around. The assembly

Parts List

- 1 PC board, code 744, available from the *EPE PCB Service*, size, 55 \times 61mm
- 1 male D25 connector, 90 $^\circ$ PC-mount (CON1)
- 1 10-pin (5 \times 2) vertical IDC header, PC-mount
- 1 10-way IDC socket
- 1 250mm length of 10-way rainbow ribbon cable
- 5 EZ-hook test clips, 40mm long
- 1 4-way DIP slider switch (S1,S2)
- 1 14-pin IC socket

Semiconductors

- 1 4011B CMOS quad NAND gate (IC1)
- 2 2N7000 *N*-channel MOSFETs (Q1,Q2)
- 4 1N4148 diodes (D1-D4)

Capacitors

- 1 10 μ F 16V radial elect.
- 1 100nF monolithic ceramic

Resistors (0.25W 1% metal film)

2 100k Ω	2 3.3k Ω
1 10k Ω	2 100 Ω

can then be completed by fitting the D25 connector (CON1), the IDC header (CON2) and the 4-way DIP switch.

Take care when installing CON2 – the 'key' slot in its body goes towards the bottom edge of the PC board.

Note that switches S1 and S2 are part of a 4-way DIP switch, with the other two switches not used. If you happen to have a 2-way DIP switch, this could be used simply by fitting it in the two righthand positions (nearer the 3.3k Ω resistors).

The 10-way IDC header (CON2) provides the interface to the I²C circuit under test. This allows you to make up a test lead cable from a 250mm length of multicoloured ribbon cable, which is fitted with a 10-way IDC socket at one end to mate with the header. Each

Resistor Colour Codes

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
□	2	100k Ω	brown black yellow brown	brown black black orange brown
□	1	10k Ω	brown black orange brown	brown black black red brown
□	2	3.3k Ω	orange orange red brown	orange orange black brown brown
□	2	100 Ω	brown black brown brown	brown black black black brown

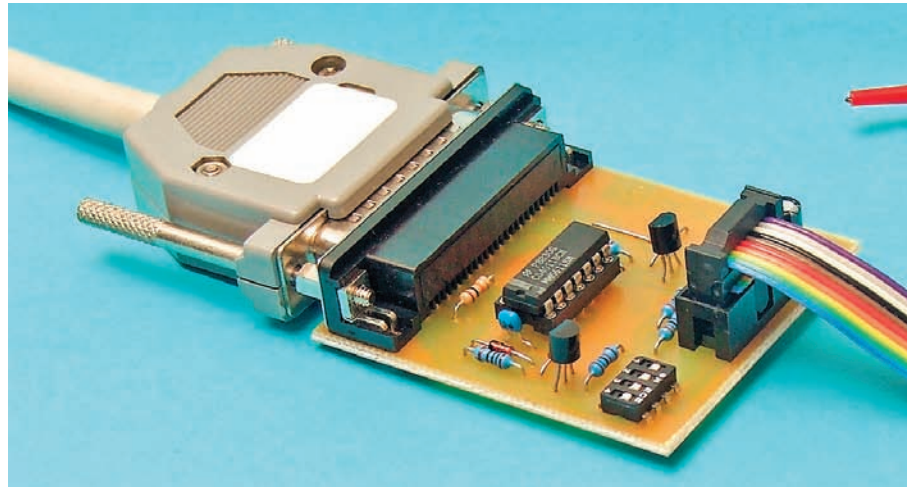
pair of wires in the cable can then be terminated in a small 'EZ-hook' test clip (see heading photo) to make the connections to the PC board being tested.

Putting it to use

There's not a great deal involved in using the interface, apart from connecting the I²C leads from CON2 to the appropriate points on the PC board you're debugging. This means connecting the SCL and SDA leads to the same lines on the board to be tested, the ground (GND) lead to the board's ground and the +5V lead to a suitable supply rail on the board.

If you're going to be using the pull-up resistors on the interface, you'll also need to connect the +3.3V lead to the positive rail of the chips connected to the I²C bus – and close interface switches S1 and S2, of course.

On the other side of the interface, all that's needed is to plug CON1 into a printer port connector on a suitable PC, either directly or via a short D25M to D25F extension cable if necessary. After that, it's simply a matter of running the URD program and using it to check and/or modify the contents of the I²C sub-address



registers inside the chips on the board you're working on.

Obtaining the URD program

To make it easier for you to get the NXP/Philips URD312 debugging program, we are posting a copy of URD312.EXE on the *EPE* Library site, accessed via **epemag.com**. If you download this and execute it, you'll find that it will install on most PCs running Win98, WinMe, Win2000 and WinXP. When it installs, it also loads the driver it needs for communicating with the interface via the printer port.

I had no difficulty installing and running the URD program on a machine running Win98, but it did have a problem talking to the printer port when I installed it on a machine running WinXP/SP2. I still haven't sorted out that particular problem at the time of writing this article, but it may be part of the tighter security enforced by WinXP when the SP2 patches are applied. **EPE**

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Recycle It!



BY JULIAN EDGAR

Super bicycle light alternator

The traditional bicycle alternator or 'dynamo' is not very effective. Here's how to turn a salvaged stepper motor into a high-power alternator for really effective lighting, even at low speed.

IN THE 'old days', if you wanted lights on your bicycle, you headed off to the corner bike shop. There you equipped yourself with a 'dynamo' (actually, an alternator) and front and rear lights, both of which used incandescent light bulbs.

These days, however, generator-powered lighting systems are out of fashion, replaced by flashing front and

rear LEDs powered by standalone AA cells. Which is fine if you don't *really* want to see where you're going and you don't *really* want to be seen by other road users!

OK, that's not quite the case – there are some excellent high-intensity LED tail-lights available on the market. And as for seeing where you're going, if you're rich, miniature halogen

headlights with their own rechargeable battery packs can be purchased.

These latter systems, some of which retail at £200 or more, provide excellent illumination, but there's a downside – the battery pack needs to be frequently re-charged. In fact, if you ride for more than an hour at night, the battery may well have insufficient capacity to last the full length of the journey. Even Luxeon LED headlights and tail-lights (see the *Universal High-Energy LED Lighting System* in the June and July '08 issues) are limited in lighting duration if you're away from a mains or car power source.

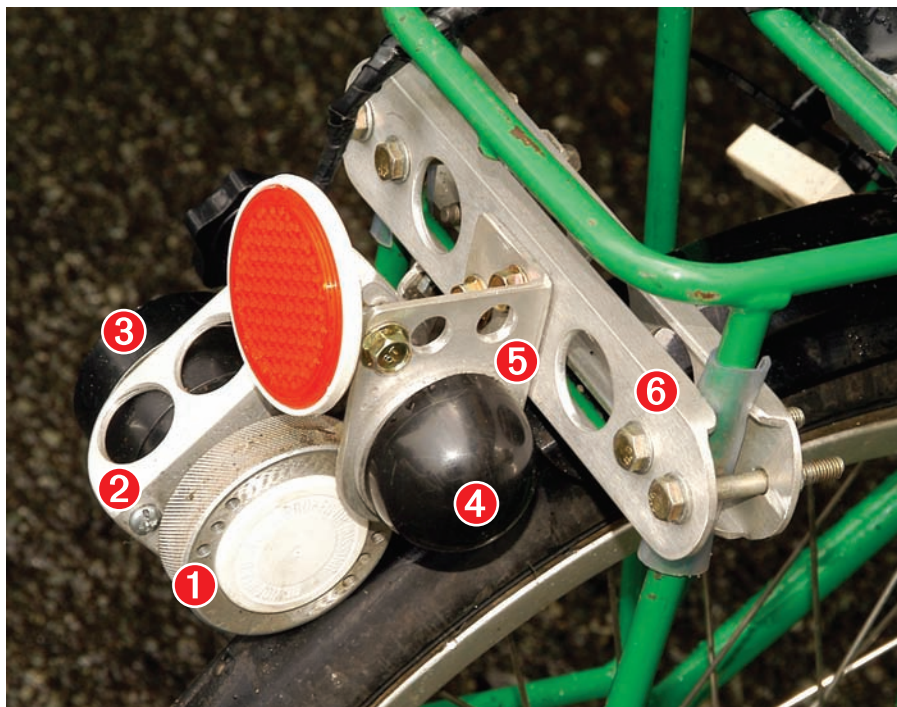
In short, if you want a lot of light over a long period, you must either carry a heavy battery pack or, alternatively, generate your own electricity as you ride along.

Generating power

A traditional bicycle 'bottle' alternator uses an 8-pole circular permanent magnet that spins between two coils. Its power rating is generally around 3W at 6V.

In all designs that aren't electronically controlled, the output voltage increases with speed. As a result, the output is 'governed' by a relatively high (eg, 14Ω) internal coil resistance to prevent the bulb's filament burning-out at high speed. In other words, go really fast and you're putting in lots more energy without getting any more out of the alternator.

A more expensive approach – one that isn't normally used in bicycle applications – is to use a stepper motor as an alternator. This approach has two main advantages: (1) a high output can be gained at low speeds, without unduly compromising the output at higher speeds, and (2) the total power output is much greater than can be achieved with a traditional bike dynamo.



The main components of the author's bike alternator system are clearly shown in this photo: (1) knurled aluminium roller made from a video drum (the white centre cap is from the top of a vitamin jar); (2) alternator support frame; (3) stepper motor (used as an alternator); (4) cover over end of video drum bearing (the cover is the cap from a deodorant bottle); (5) bearing support and (6) bike support frame.

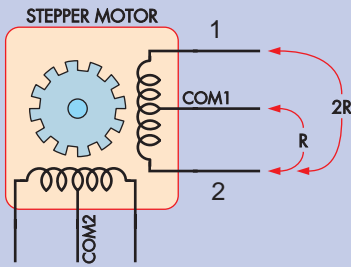


Fig.1: six-wire stepper motors have internal wiring that looks like this. When quickly sorting through a batch of possible stepper motors, placing an LED directly across a pair of wires (eg, connections 1 and 2) and spinning the stepper by hand will give a quick and easy indication of its potential power output.

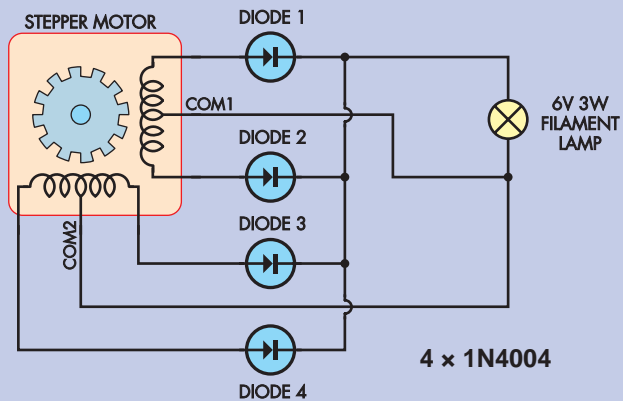


Fig.2: a further test of the alternator's output can be made by driving it with an electric power drill. As shown here, the alternator's output is rectified and connected to a suitable load, such as a 6V 3W incandescent bulb. The higher the output, the better, but as a guide, the stepper shown on these pages developed 8.4V DC at 0.6A when rotated by an electric drill at a nominal 900 RPM.

Another advantage is that if the stepper motor alternator is used to recharge a battery pack, its output voltage will remain relatively constant over a wide range of speeds.

Finally, and importantly, while they may be expensive to buy new, suitably-sized stepper motors are available for next to nothing from a wide range of discarded goods, such as photocopiers,

large printers and old electric typewriters. So, if you can scrounge one from somewhere, you'll save heaps.

Pedal power

So how much output can be obtained from a stepper motor alternator on a bike? Well, on my machine – which is actually a 63-speed recumbent trike – I've measured an absolute maximum

output of 54W! That's right – 54W, or about 18 times the output from a normal bike alternator!

Even when charging a 12V battery pack, it's possible to achieve a continuous power output of 10W at normal road speeds – over three times the output of a conventional bike alternator.

So how do you go about getting one working on your bike?

Selecting the stepper

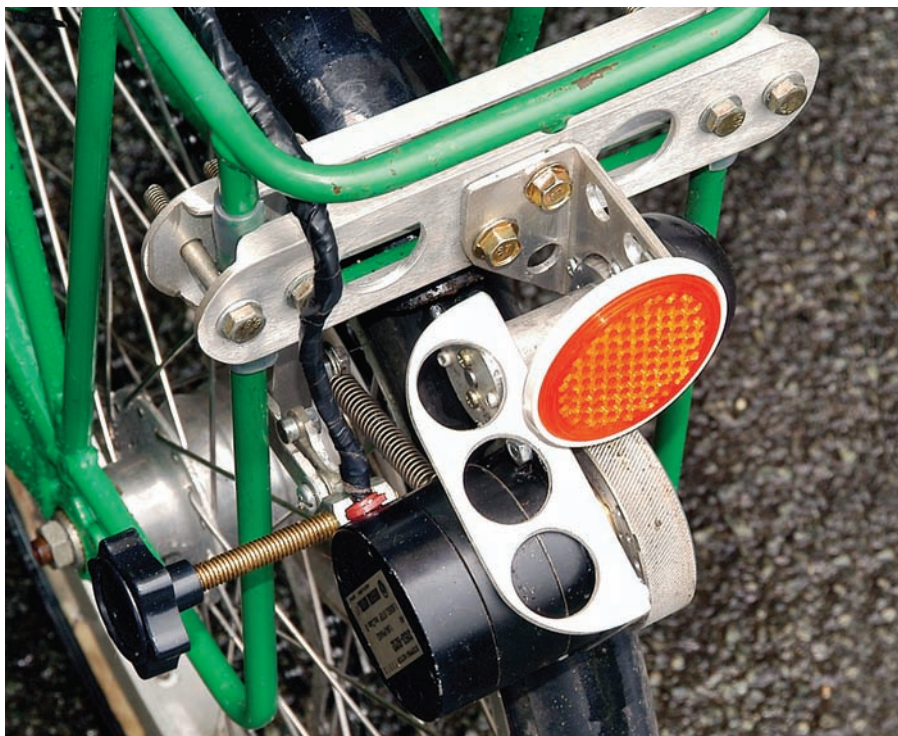
Stepper motors often look much the same, so how do you pick the best one if you've got lots to choose from?

First, go for a stepper that's decently sized. For example, the one used here is 55mm in both length and diameter. This size of stepper normally has sealed ball bearings rather than plain bushes, but you should pull it apart to make sure.

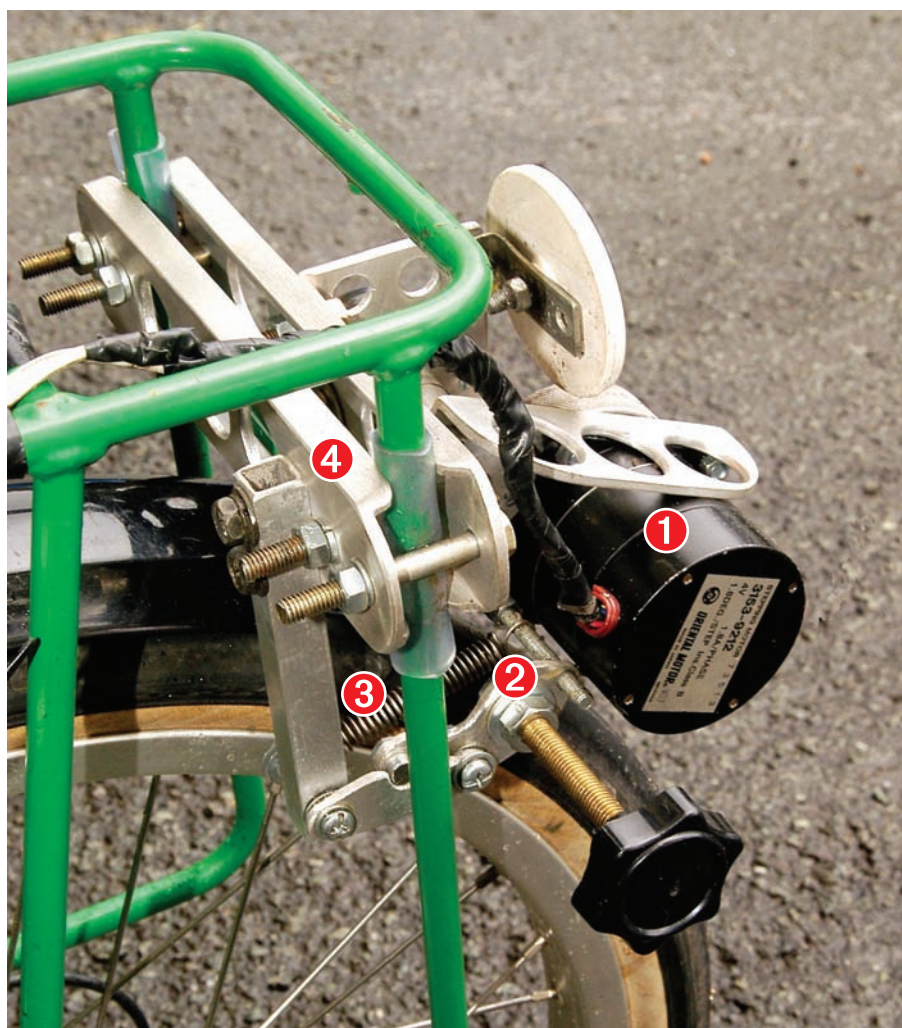
Most steppers will be six-wire designs, with two separate centre-tapped windings – see Fig.1. Use a multimeter to measure the resistances of the coils to determine which wires are which. That done, connect a high-intensity LED across one of the windings (eg, connections 1 and 2 in Fig.1) and spin the stepper by hand. The stepper you want will light the LED brightly, even with a slow shaft speed (*no, you don't need a rectifier – the LED will still light on the AC voltage*).

Next, short those two wires together. The stepper should be now much harder to turn, with a distinct 'cogging' action.

Now measure the DC resistance between these same two wires. The



The brackets that locate the alternator were made from aluminium offcuts purchased for next to nothing from a scrap metal dealer. A large number of holes were drilled in these brackets to make them light weight, while still maintaining sufficient strength and rigidity.



Here's another view of the author's system: (1) stepper motor; (2) 'over-centre' link to allow roller to be locked in lifted position; (3) spring to pull roller against tyre and (4) bike support frame.

stepper that's best suited will have the lowest winding resistance – eg, less than 5Ω .

Now for a final check. First, connect four 1N4004 diodes to the output windings, as shown in Fig.2, and connect a load – eg, a normal 6V 3W bicycle headlight. That done, use an electric drill to spin the stepper motor (which is now an alternator) and measure the output voltage and current with the load in place. The higher the output, the better – but, as a guide, the stepper shown in the photos developed 8.4V DC at 0.6A when running a 6V 3W filament bulb and being rotated by the electric drill at a nominal 900RPM.

Installing the alternator

In order to drive the alternator from a bicycle tyre, you'll need to press-fit a knurled aluminium or steel roller that's about 30mm to 60mm in diameter, on to the shaft of the stepper.

That might sound easy, but the reality is often quite different.

In my case, I have a metal-turning lathe, and so the task of making the roller was straightforward (see the accompanying 'Using a video drum as a roller' panel). If you don't have a lathe, then you might need to approach a local engineering works to make one for you.

Note that it's imperative that the roller is both perfectly round and is concentric with the shaft. The diameter of the roller is also important – we'll come back to this in a moment.

Rather than take the traditional approach of the roller pushing against the sidewall of the tyre, I chose to run the roller against the (semi-slick) tread of the tyre. This allows the use of a larger diameter roller, while still letting the roller run true.

However, there is a problem with this approach. Most salvaged stepper

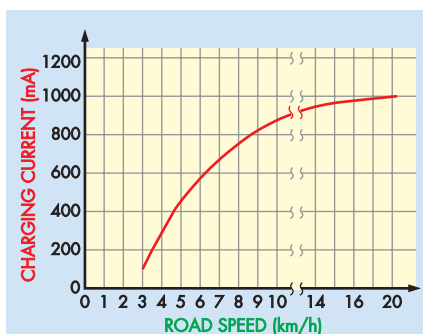


Fig.3: the current achieved when charging a nominal 4.8V NiMH battery pack with a six-wire stepper motor with these specifications: 4V, 1.8° per step, 1.8A per phase. The alternator uses a 63mm diameter knurled roller, contacting the tread of a 20-inch slick tyre. Note the high output at very low road speeds – even when using the large diameter roller, 800mA charging is achieved at just 9km/h.

motors have only a short length of protruding shaft. If you mount a wide roller on this, much of the roller isn't supported by the shaft and so the roller will have a tendency to wobble.

In my case, I chose to use a narrow roller that is better supported by the shaft, but bears against only the centre of the tyre tread. This works very well, with no detectable slippage, even in wet conditions. However, if the bike is to be used in muddy conditions or has a treaded tyre, a smaller roller that bears against the tyre sidewall should be used.

The alternator/roller combination needs to be mounted so the assembly can pivot, pushing the roller against the tyre. At its simplest, this requires only a few brackets and a normal door hinge, but I chose to make a more elaborate mount.

Stationary Power Station

Another application for a converted stepper motor alternator is on an exercise bicycle. In this case, a small diameter roller should be used, and by feeding the output into a suitable charger, you can recharge batteries while you exercise.

That's a lot more useful than just dissipating your energy into a friction brake!

Using The Luxeon High-Energy Lighting System

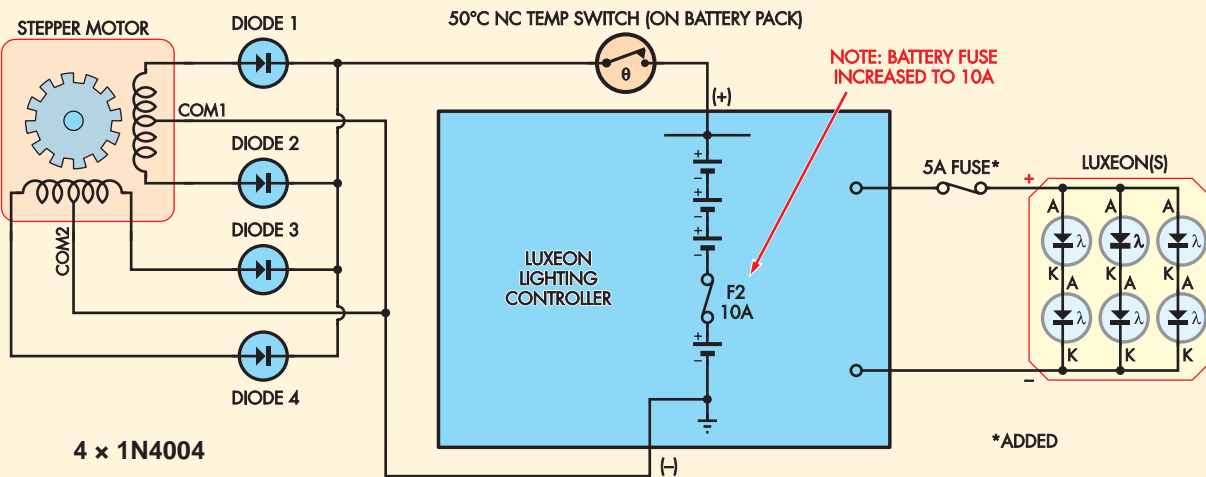


Fig.4: a very effective bike lighting system can be made by using the alternator to charge the battery in the *Universal High-Energy LED Lighting System* mentioned earlier. As shown here, the alternator is directly connected to the battery pack via a 50°C series temperature cut-out, the latter mounted on the battery pack. In addition, a 5A fuse is added in series with the Luxeon output, and the battery fuse is upgraded from 5A to 10A.

The best light sources for bike lighting systems are Luxeon LEDs. And in my opinion, the best control system for Luxeons is the *Universal High-Energy LED Lighting System* described in *EPE* June and July '08 issues.

In addition to efficiently operating LEDs up to 6W, the system has specific bike light modes that alter flashing rates according to the ambient light levels.

However, you can't just connect the rectified output of the alternator to the charging socket of the Luxeon system to recharge the batteries. Why not? Well, since the no-load output of the alternator can be as high as 80V, this would destroy critical parts in the charging circuit. This occurs because once the input voltage exceeds 18.6V, charging automatically stops, and so the alternator sees a no-load condition and its output voltage sky-rockets.

The best way to integrate the Luxeon system with the alternator is shown

in Fig.4. As shown, the alternator's rectified output is directly connected to the battery pack through a 50°C series temperature cut-out (ie, the input charging circuit is bypassed). The temperature cut-out is mounted on the battery pack and prevents overcharging (the battery pack gets hot if over-charged).

In addition, a 5A fuse is added in series with the Luxeon LEDs, while the existing 5A battery pack fuse (F2) is upgraded to 10A. These fuse changes prevent a scenario where if the Luxeon output is shorted, the battery fuse blows and the rest of the circuit sees 80V courtesy of the unloaded alternator.

In practice, the new charging cable from the alternator can be routed through the existing cable gland (there's just enough room for the two cables). Note that when using this revised configuration, the coloured LED will constantly show battery

level – it won't change to indicate when alternator charging is occurring. If required, 'top-up' charging of the battery pack can still be carried out using an external plugpack, and in this situation, the charge LED will work as usual.

When charging the Luxeon system's NiMH battery pack, the alternator used by the author gave a measured output as shown in Fig.3. Note that as the road speed (and thus the alternator speed) increases, the rate of current increase begins to flatten out.

The trick is to gear the alternator so that there's still plenty of power available at low speeds, but without the current output reaching a plateau early in the normal speed range. Another point to note is that the author's alternator was internally current limited to 1A. So in this case, when charging a battery pack at about 5V, the peak power obtainable from the alternator was 5W.

As shown in the photos, I used the parts from a couple of video drum assemblies (salvaged from VCRs) to make a suitable assembly. First, one part of a video drum was used for the roller itself (see panel). That done, the main shaft support – which contains two widely spaced bearings – was reduced in diameter, as was

the spinning head (note: all video drum components except the shaft and bearings are made from easily worked aluminium).

The stepper motor was attached to a cut-down spinning head via a bracket made from aluminium angle. The other part of the drum assembly, comprising the precision sealed ball

bearings and support, was attached to another aluminium bracket, which in turn was bolted to a plate. This plate was then attached to the cycle carrier (note: the aluminium plates and angle brackets were drilled for lightness).

The video drum shaft and its bearings form the pivot on which the stepper motor/roller assembly

rotates. This arrangement allows the roller to be pressed against the tyre while rigidly keeping the stepper motor shaft in parallel with the wheel axle.

Because the roller has a relatively large diameter, it doesn't need to be pushed hard against the tyre. A light spring will do the job, without an appreciable tyre deflection – and without the frictional losses that would otherwise result. (Note: because the stepper has a high output at low speeds, a small roller is not needed).

I also added an 'over-centre' linkage in parallel with the spring. This allows the alternator to be held captive in a lifted position, if required.

Roller diameters

It is not just the characteristics of the stepper motor and the load that determine the electrical output from the stepper – it also depends on how fast the alternator turns.

In practice, the alternator speed is determined by tyre diameter, the drive roller diameter and how fast you ride. This latter point is often forgotten, but if you seldom exceed 10km/h, the gearing of the alternator will need to be quite different than if you frequently ride at 25km/h.

An alternator subjected to a load will have an output current that initially rises with speed and then levels off as the speed rises further. If the alternator is geared too high, the output current will limit early. This is bad because you'll be pedalling hard but getting no more out of the alternator.

On the other hand, if the alternator is geared too low, the electrical output will always be less than it could otherwise be.

Because the optimal alternator gearing depends on the load, the characteristics of the alternator and how fast you ride, the best approach is to try some different diameter rollers. The first roller I made was 33mm in diameter. This gave excellent electrical output, but the pedalling effort (even with no current draw) was relatively high (this 'parasitic' load is due to internal hysteresis losses).

Using this roller on a 20-inch tyre gave an output of 12.7V and 0.8A when pedalling at 15km/h. This output was used to charge a 9.6V NiCad battery pack. At over 10W output, there was



When the over-centre lever (1) is released by turning the knob clockwise, the alternator/roller assembly pivots so that the roller contacts the tyre and is held there by a spring. The pivot is formed from a cut-down video drum assembly (2) that uses high quality ball bearings and a precision shaft. Note that a strong spring is not needed, as the large diameter knurled roller grips the slick tyre quite well.

power to spare, so I decided to try a larger 63mm diameter roller to slow the alternator and decrease the parasitic losses. This new roller reduced the pedalling effort and the electrical power output remains quite respectable.

Conclusion

It's not a five minute job, but with a little time and patience, a salvaged

stepper motor can be turned into a very effective high-power bike lighting alternator.

EPE

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Using a video drum as a roller

As stated on previous occasions (see May '09), the drum assemblies from VCRs are worth salvaging. In fact, one can be used to make the roller that drives the bike alternator.

When you pull the video drum assembly apart, you'll find a hardened steel shaft that runs on sealed ball bearings. At one end of the shaft is a brass collar that is a push-fit on to the shaft. Bolted to the collar is the part of the drum that spins. This comprises a 61mm diameter 12mm wide aluminium disc.

The shaft of the video drum is a little smaller in diameter than the shaft of most medium-sized stepper motors. So, if the brass collar is removed

(easily done by using a vice to support the collar and tapping the shaft with a hammer), it can be carefully drilled-out to become a push-fit on the shaft of the stepper.

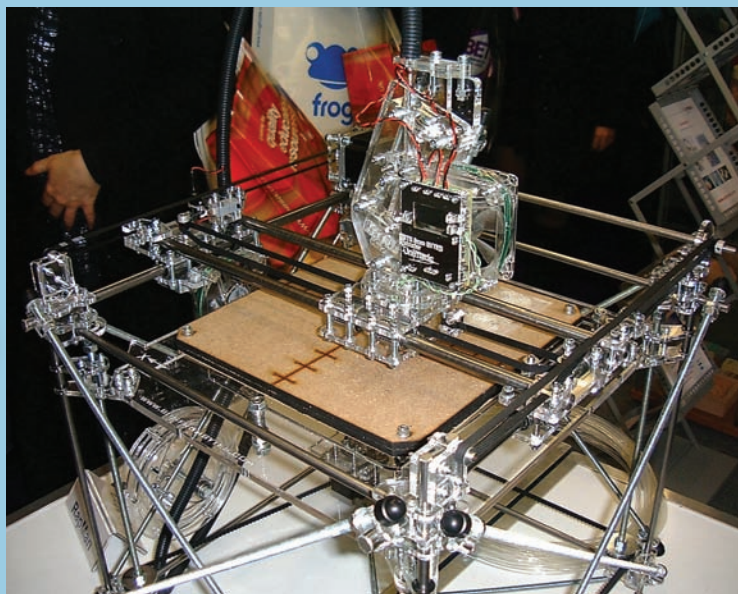
If the hole in the brass collar ends up a fraction too large to be a genuine push-fit, squeeze the shaft of the stepper in the hardened steel jaws of a vice. This will raise corrugations in the metal which will then grip the collar quite well. You can then apply some Loctite for additional security.

The drive surface of the aluminium disc can be knurled in a lathe (or have lateral striations cut across it with a file or hacksaw) and then bolted to the brass collar.

RapMan – The 3D Printer

Part 3

by Mike Hibbett



Introducing the ‘RapMan’ a low cost 3D Printer – setting up and using

IN the last two articles, we described a commercial 3D printer, RapMan, and detailed its construction. While the construction of the machine was a great experience, the purchase of a kit like this isn't motivated solely by a desire to play with 'Meccano' but with the intention of building things. So this month we wrap up by exploring the initial setup and use, including the extended software tools required.

Getting started

As already mentioned, no mains cable or SDMedia card are supplied with the kit, but these were readily available. The mains cable is the common IEC type and the SDMedia card can be found in many electronic gadgets around the house, and are available on eBay for a couple of pounds (should your children not want to lend you theirs!)

Only a short length of plastic extrusion material is supplied, so it is advisable to purchase some when buying the kit. ABS is the best material to start with as it is easy to work with and produces very strong objects that can be drilled and tapped. Cases made from this material are often stronger than the usual general purpose project boxes.

Plastic is purchased by the kilogram and is supplied on reels not dissimilar to rolls of wire. One kilogram of ABS goes a long way as a typical print (say, a small project case) consumes only a few tens of grams, and has little waste. However, we did waste about ½kg during initial testing, mostly during experimentation with different design tools and model designs. Appreciating how a 3D model translates to a real object takes a bit of getting used to!



Fig.1. Extruder tension screws

Initial setup

There are two essential setup steps that must be followed – levelling the print platform, and adjusting the extruder clamp screws. Platform levelling is essential to allow the print-head to be within 0.1mm to 0.2mm of the print surface. Much more than this and you will find that the plastic will not stick to the platform as the first layers are deposited.

Full details are provided in the user guide, and the process is just one of careful adjustment of the three spring-loaded support bolts. It's important to keep an eye on this over time as parts may shake loose and the print platform can deform slightly. The author checks his about twice a month.

Getting a good feedrate of plastic into the extruder head is also very important. Two things affect this: how smoothly the plastic reel holder rotates on the spindle, and how tightly the two spring-loaded tension screws hold the material against the extruder motor.

Fitting the plastic reel-holder to give a smooth, freely rotating support was a bit 'hit and miss'. The author re-fitted it several times before

settling on a position that gave minimal resistance to the pull of the extruder.

Regarding the tension screws, a simple rule of thumb is that you should be able to fit your fingernail easily between the springs. If you have the screws too loose then you will get erratic feedrates, which results in 'thinning' of the extruded plastic and an uneven finish. The position of the tension screws is shown in Fig.1.

Note: there is a lot of plastic dust in the extruder; this is not an issue and does not interfere with the operation of the machine. Our's gets a 'vacuum' once a month just in case though!

User guide

The user guide is simple and straightforward, providing the key details for getting started. There is, however, a lot to learn that simply cannot be conveyed in a simple document.

Fortunately, BitsFromBytes host a web forum which is a very friendly and (more importantly) a very helpful community. Most of the chatter is between those who have recently completed construction and those who have been using their machine for a few months. While the BitsFromBytes staff help out from time to time, questions are normally answered swiftly by other kit owners, which is a good sign.

For those new to mechanical engineering or the science of plastics, there are either experts on hand, or people who have been through the same issues. The web forum can be found at the main BitsFromBytes home page. A 'Wiki' (a series of web pages that can be modified by users directly from a web browser) is also in development; once again, being constructed by RapMan owners as much as BitsFromBytes staffers.

Controls

Before describing the software tools used in the creation of models, we will take a tour of the RapMan's user interface.

All of the control electronics are located on a single pre-assembled PCB at the front of the machine, as shown in Fig. 2. The machine is controlled by seven buttons and feedback is provided through a small colour OLED graphics display. There is no power switch, but the machine boots up into an operational state within a few seconds of applying power.

RapMan has four operational modes, with the buttons performing different functions depending on the mode. This caused a bit of confusion at first (solved by keeping a list of the functions beside the machine.) Two of the operational modes are only used when setting up and testing the properties of a new plastic; in reality the machine is very simple

to operate, as files are prepared on a PC and transferred to the machine with an SD card.

The normal print process is to simply insert the SD card, press a button to select 'Print', and then a single button press to confirm the file name. There have been questions about why the machine does not permanently connect to a PC; the simple fact is that it doesn't need too, and having a PC left switched on for hours at a time unnecessarily wastes electricity.

Operational modes

Now let's examine the four operational modes: *Menu*, *Tool Setup*, *Manual Move* and *Print*.

On start-up, the machine enters 'Menu' mode, where a simple list of options is presented, enabling the user to select one of the other modes. Selecting 'Print' displays a list of the print files held on the SD card, and you select one using the up/down buttons on the right and the far right key to confirm. The most recently added file appears first in the list, which is a nice touch and makes printing a two button press operation.

Selecting 'Tool Setup' starts the extruder motor running and allows you to control the speed at which the extruder runs, and the temperature to which the plastic is heated. This is purely for experimenting and fine tuning when using a new plastic, and



Fig.2. Control electronics



Fig.3. Print progress

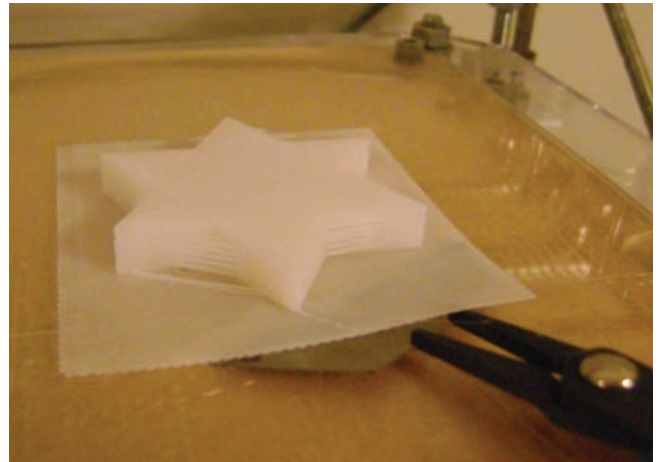


Fig.4. Removing a print

is rarely required as there are many experienced users who provide this information on the Forum.

The 'Manual Move' option enables you to manually move the extruder in the X/Y planes, and the print platform up and down. This is useful during construction of the machine, but rarely used in normal operation (we've only used it when lubricating some of the parts, which could really be considered part of construction.)

Printing

On selecting a file to print, the machine first pauses while the heater barrel comes up to the correct temperature. The display shows details of the current temperature and the target temperature, as shown in Fig.3. Heating takes a few minutes and during this time the heater nozzle leaks a small amount of plastic, which one usually removes with tweezers to avoid it becoming part of the print (although it's easy enough to clean up afterwards.)

Once the correct temperature has been reached, the extruder starts printing a raft, the two layer square platform onto which your actual object will be printed. This provides a very uniform base for your object and ensures that it will properly 'stick' once it starts printing. The print process relies on the extruded plastic sticking to the previous layers, and this can be difficult with dissimilar materials (the print platform is acrylic, for example.)

The first layer of the raft is printed at a temperature which ensures the material bonds slightly to the print platform, and then successive layers are printed at the optimum

temperature for your chosen plastic. Again, it's not something we have to concern ourselves with as the optimum settings have already been worked out for us and are pre-programmed into the PC software.

Print progress is shown on the display as a bargraph, which can help you estimate completion time. Printing time can be hard to determine, as it depends on the complexity of the object, and how that complexity translates into extruder head movement.

Once the print has completed, and a few minutes allowed for it to cool down, it is removed by sliding a thin metal ruler or blade underneath the raft. The raft is then removed by simply tearing it off. Minor blemishes, such as residue from the raft or filaments of plastic left over from the extruder head movement are removed using a scalpel. Fig.4 shows a finished object being removed from the platform.

ABS is a wonderful plastic to print with. The final objects are very strong and can be drilled and tapped if required. ABS parts are also very easy to glue together and it's not uncommon to see a complex object constructed from several smaller, easier to print parts.

Production process

Let's now go back a few steps and look at how we create designs to print. It's a little more complicated than 2D printing as there can be a number of programs involved, certainly at least two. The process, however, is straightforward: Create your 3D drawing, convert it to the format required by the printer, and then print it.

Drawing the object to print requires a 3D CAD or modelling program. For

the uninitiated, this is likely to be one of the more challenging issues, as 3D drawing programs do tend to be more complicated than 2D ones. There are many commercial applications on the market, and several free ones, but we have decided to take a look at the free ones only.

We focused on how quick the learning curve was for each, and how easy it was to produce a simple project case.

Art of Illusion by Peter Eastman is a completely free 3D modeling application and is very powerful, with many features. It's also very popular among the 3D printer community.

We found the learning curve a little too steep, but comments received suggested that it's worth investing the time in learning its features.

Google Sketchup 7 is also very popular, and is certainly easy to use. It's available in both commercial and free variants, although the free version cannot save data files in a format suitable for use with the printer. Fortunately, a free file converter is available, which we have tested and appears to work, so that is not such an issue.

While easy to use, we did find it difficult to create the design we had in mind, but once again this is probably something that can be learnt over time. There are several good tutorial books available for Sketchup, which would, of course, help the learning process.

CoCreate by PTC is a full specification commercial 3D modeling application. Somewhat unusually, PTC allow the application to be used free for personal non-commercial use.

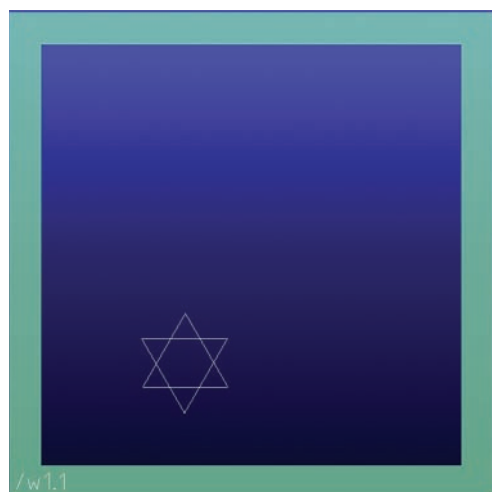


Fig.5. 2D star drawing

Although it is a very large download, the program installed easily, and with the help of the startup tutorials we were designing our case part within an hour. It's surprisingly easy to use, and as a plus generates files in a format compatible with RapMan.

For the time being we are sticking with CoCreate, but are putting the effort into learning Sketchup, as this is likely to become more popular given its smaller size and famous publishers (Google.)

CoCreate in use

It's close to Christmas as we write this article, so we will do a simple example design with a Christmas flavour – a star shaped decoration for the tree.

On start-up, CoCreate displays a 2D workplane (shown as /w1) and so the first thing we need to do is draw a simple six-pointed star, using the 'Line, 2 Pos' tool. As you finish one line segment and start another, the cursor will display a small square to indicate that it is positioned directly over the end. This is a key thing to note when drawing lines free form, as you cannot later convert incomplete shapes into 3D objects.

To get as good a six-pointed star as possible, we drew two triangles, as shown in Fig.5, before trimming away the unused detail. The dimensions of the drawing are in real sizes, so if an edge is 25mm long on the diagram, that's how long it will be when printed out.

Next up, we convert this into a 3D object using the 'Machine' menu options. The 3D tools have familiar machining names, such as turn,

mill, punch or extrude and will be instantly familiar to some. For the rest of us, it's a case of trial-and-error coupled with judicious use of the 'Undo' option!

Eventually, selecting the 'Extrude' option, we were presented with a very intuitive interface for stretching the object out of the 2D plane and into 3D. You can manually set the size using the mouse, or type the thickness into the toolbox on the lefthand side, as shown in Fig.6.

And that's it, a star is born. All that is now required is to save the file in the correct file format.

File formats

CoCreate has its own database format for saving drawings, but needless to say it's a proprietary format that cannot be read by other applications. There is, however, an industry standard format for 3D object files called STL, which is used by RapMan and is a supported 'export' file type within CoCreate. It's a simple file format that describes objects as a series of triangles.

You will still want to save the drawing in CoCreate's default format first, as this contains additional information required by CoCreate should you wish to continue editing the object at a later date. For now, we simply saved the file, then selected 'Save' again and changed the 'file type' to STL.

Now that we have an object defined and stored in a definition file, we have to convert that object description into a 'G code' file. G codes are another industry standard file format, and are used to describe the control

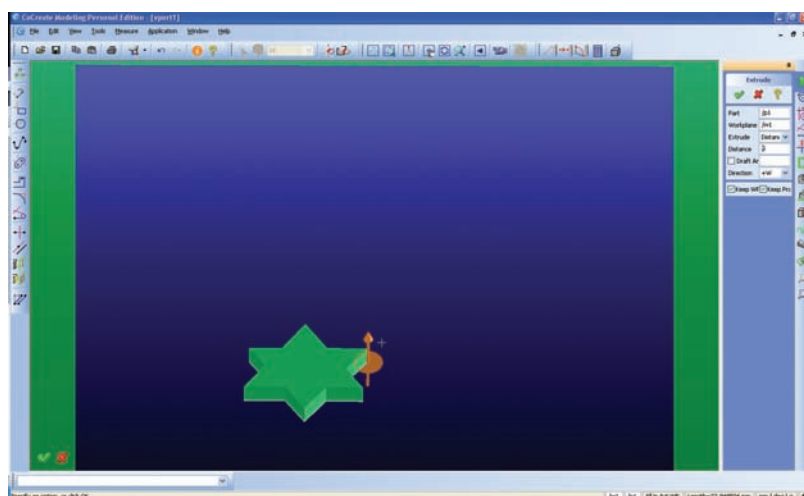


Fig.6. Extruding an object

of a tool in a CNC machine. Unlike STL, it's a fairly loosely controlled standard, but BitsFromBytes specify a particular program for the generation of this file, and their RapMan firmware has been designed to be compliant with it.

Skeinforge is the application that has been created to convert .STL files to G code files. Written by Enrique Perez, it now has a strong following of engineers and hobbyists. Converting an object definition into a series of commands for a tool head (be that a milling machine or a 3D printer) is an incredibly complicated task. Skeinforge does a very good job at it, most of the time, and is completely free.

As Skeinforge is responsible for producing head movement speeds, extrusion rates and extrusion temperatures, there are, as you might imagine, many configurable options too choose from. Once again, the RapMan community has come up with suggested settings that appear to work fine, so the first-time user is not faced with a multitude of options to deal with. You simply run the program, select your .STL file and wait a few minutes for the G code file to be produced.

Now, it's just a case of transferring the file to an SD card, placing it in the machine and pressing print. Fig.4 shows the completed star being removed from the platform. We gave it a quick spray with gold paint before placing it on the tree.

The star is a trivial example, but we have also created a case for last month's *Pic n' Mix* project, which can be downloaded from the *EPE* website. You can view it within a 3D

drawing program or even print it if you have been tempted by our special offer, and obtained a RapMan.

Of course, you do not have to create your own designs to print; you can download existing designs created by others. There is already a thriving community sharing different works and a website (see Ref.1) has been created to host such designs, and allow people to download and comment on them. In the near future, it should be possible to look up common items, spare parts for your dishwasher and so on.

Advanced printers

The author has seen dozens of different 3D printer machines using almost as many different printing processes. Most of these machines are priced in the hundreds of thousands of pounds, but there are a few that are approaching the newly evolving low cost market.

The 'uPrint Personal 3D Printer' from Dimension, while costing almost twenty times that of RapMan, is capable of some impressive results. By implementing two print heads it is able to lay down *support material* – another material that can 'fill the gaps' between layers of plastic, but then be washed away once printing is completed.

Complete mechanical assemblies, such as the three-part spanner design shown in Fig.7 can be printed in a single pass. After a simple wash cycle, the fully functioning spanner shown in Fig. 8 was produced, with no assembly required. While you won't be repairing your car with a spanner like this, it was perfectly able to adjust the bolts on our own printer.

BitsFromBytes are working on a second print head option for support material for their own printer, which will be interesting to see.

EPE Reader Offer

The RapMan printer kit is available from www.bitsfrombytes.com. For readers of *EPE*, BitsFromBytes are offering a 15% discount on all products. Just enter the code **EPEYRK** when prompted for a coupon code on the Cart screen prior to Check Out.

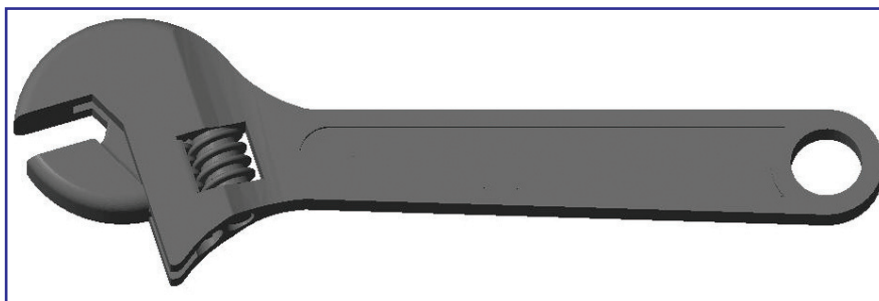


Fig.7. Spanner design



Fig.8. Printed Spanner

Final conclusion

RapMan is great! It brought back all the positive memories of building Heatkit projects, and has opened up a whole new dimension to our hobby – creating useful objects out of plastic. We have discovered new mechanical engineering skills, the science of plastics, and found a new outlet for our ingenuity and imagination. Rather than thinking 'Where can I buy that?' it's now 'How can I make that?'

Building RapMan will be difficult for someone unfamiliar with assembling Meccano, but the process will not be impossible and certainly will not be frustrating. Some construction steps took longer than we would have liked, but getting through this quickly should not be seen as a priority – enjoy the build process, and learn about the machine you are constructing.

We hope that RapMan is the start of a revolution in product manufacture, the first step towards bringing the process into the home. One day, a 3D printer will be as cheap and common place as a microwave oven.

RapMan is already finding uses in the author's home, creating replacement parts for the dishwasher, washing line, several doorstops and providing simple toys for the children. Electronics projects become more exciting when you have the opportunity to create a slick custom

case for them, and robotics projects can become far more complex, and cheaper.

A 3D printer can remove several companies from the product supply chain. Imagine you want a replacement part for your dishwasher; a company had to create a drawing for the part, find a manufacturer that would make it, that manufacturer would have to obtain the raw material, make it, ship it to a distributor, who would then ship it to a retailer, who would then keep it in stock until you come along and purchase it. With a RapMan machine you would simply download the designer's drawing and print it. The environmental savings alone will be significant. The future is looking interesting!

Postscript

The concept of 3D printers in the home has already been covered by science fiction writers. Cory Doctorow's short story *Printcrime* is published on the Internet and can be viewed here: <http://craphound.com/p=573>. As a piece of science fiction it's quite an amusing read, given that having a 3D printer in the home is now a reality.

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- Ref.1. Thingiverse – www.thingiverse.com
- Ref.2. BitsFromBytes website – www.bitsfrombytes.com
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TEACH-IN 2010

LADDER LOGIC PROGRAMMING

FOR THE PIC MICRO



Part 4: Counters and Pulse-Width-Modulated Waveforms

By Walter Ditch

PART four of this series on ladder logic (PLC-style) programming for the PIC micro continues the tour of sequential logic features by looking at counters and the generation of pulse-width-modulated (PWM) waveforms. (Recall that previous instalments have covered topics including inputs and outputs, combinational logic, oscillators, latches, timers, shift registers, byte transfer and byte comparison commands.)

These building blocks have been used to construct a number of simple systems, using a programming approach called ladder logic, which has close parallels to the design and construction of electronic circuits. Thus, the designer (that's you!) simply uses ladder logic program statements to connect together the required electronic building blocks in order to construct a fully working system.

A machine code program is then automatically generated for the chosen PIC microcontroller by using the assembler's macro substitution feature. This process has close parallels with the use of a compiler to convert a high level language program (such as BASIC, Pascal or C) into machine code – including, of course, the inevitable increase in size of the final machine code program.

It must be admitted that the macro substitution method used here lacks some of the sophistication of a true

high level language, such as syntax checking and meaningful (high level) error messages. However, electronics enthusiasts should find it relatively easy to write ladder-logic-style programs, and the source code programs are normally very concise.

I hope that you will use the techniques presented here in order to adapt the example programs, and to develop new ladder logic programs. It really is most satisfying to see your own design running on a small piece of silicon, performing tasks exactly as you intended!

Software

As explained previously, all program listings for this series are available from the Library > Project Code section of the *Everyday Practical Electronics* website (www.epemag.com). You'll also need the header files supplied with Part 1, which should be 'unzipped' into a single folder, together with the sample files from each part of the series.

Make sure you have installed the freely available MPLAB IDE software, which will be needed to assemble the example programs. And of course, in order to actually test the programs, you will need a suitable PIC development board, fitted with one of the supported PIC microcontroller types, or simulation software such as Proteus VSM from Labcenter Electronics.

Counter applications

As their name suggests, counters are used when you need to keep track of the number of times an event has occurred. In its most basic application, the counter simply provides a signal when the predetermined number of input signals has been detected – as in a simple unidirectional counter. Counters are also available which can count up or down – a bidirectional counter. Both types of counter maintain a running total of the number of inputs received, in addition to the more basic finished/not finished status output.

Counters may be used as building blocks in a wide variety of more complex designs, with motor control being a typical application. For example, linking a counter to a stepper motor controller will allow a simple position control system to be created. It is also possible to vary the speed of a DC motor by using a counter as the input to a variable PWM waveform. In this case, a unidirectional counter would provide a 'soft start' feature, and a bidirectional counter would allow the motor speed to be dynamically increased or decreased.

Unidirectional counters may also be combined with oscillator signals to create custom time delays, as will be seen shortly.

Unidirectional counters

The PLC software provides up to eight unidirectional (up only) counters, plus a further eight bidirectional counters. Operation of a basic unidirectional counter is quite similar to that already seen with timers, which should come as no surprise, since a timer is little more than a counter with an oscillator hard-wired to its input. A simple unidirectional counter application is illustrated by the example of Fig.4.1.

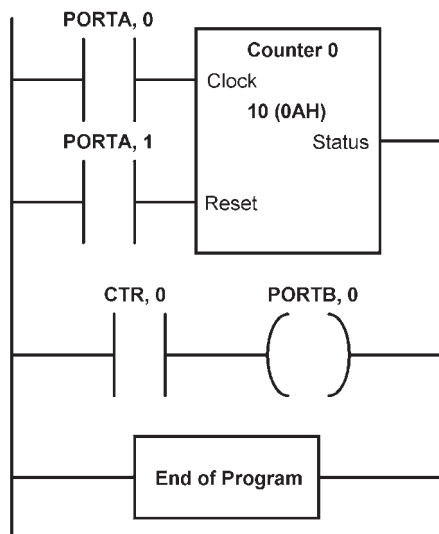


Fig.4.1. A simple counter circuit, shown in ladder diagram form

The previous input value provides the clock input to the counter, which is typically the result of a 'ld' or 'ld_not' instruction. The first parameter actually supplied to the 'ctr' command is the counter number, which must be in the range 0-7. Remaining parameters are the final value (1-255), followed by the reset register and reset bit (0-7).

Each rising edge of the Clock input causes the internal counter register to increment. The counter's Status bit becomes set when the counter reaches its pre-programmed final value, which is in the range 1-255 (a final value of 10 is shown in the example of Fig.4.1). The counter's status bit is available from the

equivalent bit of the CTR register (so, for example, bit 0 of the CTR register holds the status bit for counter 0). Both the internal count value and the status bit are cleared by applying a logic 1 to the Reset input. So, the Reset input must be held low during normal operation of the counter.

The internal count value is not required in simple counter programs, so it is sufficient to know that the counter is either finished (Status = 1), or in progress (Status = 0). However, internal count values are available, if required, from registers CTR0-CTR7 respectively, and this running total may be used in more advanced applications. (An internal count value will be used later as part of a motor speed controller system, and further counter-based applications will be explored in Part 6.)

An equivalent program is given in Listing 4.1, written for the PIC16F88 microcontroller, and with low voltage programming enabled on bit 3 of Port B.

The program uses the result from the previous command as the Clock input (obtained by reading the state of Port A bit 0), while Port A bit 1 provides the Reset input to the counter. The Status bit for counter 0 is loaded from bit 0 of the CTR register and is displayed on Port B bit 0.

This is one program which may give a visibly different result when tested

on a simulator, such as Proteus VSM, compared to a real PIC development board – and the difference is no fault of the simulator. Switch bounce is an unwanted effect associated with real switches, and can cause the counter to jump forward by an unpredictable number of steps for each key-press. Fortunately, a software-based switch debounce circuit has already been developed (refer back to Listing 3.3 and associated text) which can be easily added, as given in the program of Listing 4.2.

On-delay timer

You can see that the original input to the counter (bit 0 of Port A) is now used to drive an on-delay timer having a delay of 12ms. The output of the on-delay timer (bit 0 of register TIMH) in turn becomes the input to the counter, with the remainder of the second program being identical to the first. A useful exercise is to load the programs of Listings 4.1 and 4.2 on to a suitable development board, comparing the actual number of switch presses required to set the counter's Status bit – the first may vary and the second will be exactly ten switch presses every time.

As mentioned earlier, it is easy to create a custom timer by combining an oscillator waveform and a unidirectional counter. Referring back to Part 2, Table 2.1, it can be seen that a variety

```
include "16F88_L.PLC"      ; Defines PLC instructions
                             ; (Low voltage programming enabled)
ld      PORTA, 0            ; Read Port A bit 0 (clock input)
ctr      0, 0AH, PORTA, 1   ; Counter 0
                             ; Final value = 10 (0AH),
                             ; Reset = Port A bit 1

ld      CTR, 0              ; Read counter 0 status bit (1 = finished)
out      PORTB, 0           ; Output counter 0 status to Port B bit 0

endp                        ; Marks end of PLC program
```

Listing 4.1. Counting pulses using a unidirectional counter (Lst4_1.asm)

```
include "16F88_L.PLC"      ; Defines PLC instructions
                             ; (Low voltage programming enabled)
ld      PORTA, 0            ; Read Port A bit 0 (Count input)

timh     0, 03H             ; High Speed Timer 0, final value = 3
                             ; (T = 3 x 4 ms = 12 ms)
ld      TIMH, 0             ; Read timer status bit (debounced input)
ctr      0, 0AH, PORTA, 1   ; Counter 0, final value = 10 (0AH),
                             ; Reset = Port A bit 1

ld      CTR, 0              ; Read counter 0 status bit (1 = finished)
out      PORTB, 0           ; Output counter 0 status to Port B bit 0

endp                        ; Marks end of PLC program
```

Listing 4.2. Adding a debounced switch input to the simple counter application (Lst4_2.asm)


```

include "16F627.PLC"           ; Defines PLC instructions

ld      OSCL, 6                 ; 8.389 s periodic time clock input
ctr     0, d'143', PORTA, 1    ; Counter 0, final value = 143
                                   ; Reset = Port A bit 1
ld      CTR, 0                 ; Read counter 0 status bit (1 = finished)
out     PORTB, 0               ; Output counter 0 status to Port B bit 0

endp                             ; Marks end of PLC program

```

Listing 4.3. Using a custom timer to create a 20 minute delay (Lst4_3.asm)

of oscillator frequencies are available from registers OSCH and OSCL, with period times ranging from $512\mu\text{s}$ to 16.77 seconds. Combining these inputs with the ability to count from 1-255 input cycles gives an incredibly wide range of potential time delays, ranging from a few milliseconds up to a maximum of 255×16.77 seconds, or 4,276 seconds (approximately 71 minutes).

As an example, let's assume that a time delay of 20 minutes (1200 seconds) is required – for a burglar alarm time-out perhaps. A quick calculation shows that $1200 \text{ seconds} \div 255$ would require a period time of 4.7 seconds, which unfortunately is not directly available from the OSCL or OSCH registers.

However, from Table 2.1, the next higher period time is 8.389 seconds, which is available from bit 6 of the OSCL register. A quick calculation shows that a count value of 143, combined with a period time of 8.389 seconds would give a calculated time delay of 1199.627 seconds, which is very close to our required time delay value. Listing 4.3 shows how this might be coded for the PIC16F627 microcontroller.

Don't expect this program to do anything too exciting – it takes 20 minutes just to turn on a single LED! However, it might be useful to combine this custom timer with the burglar alarm program previously seen in Listing 3.2, in order to provide a more practical time-out period. (This is left as an exercise for the reader.)

Longer delays

If even longer delays are required, then it is possible to cascade multiple counters, in a similar way to the shift registers seen in Part 3. You can link up to eight counters, thus creating a single hybrid counter/timer up to eight bytes wide. The trick in this case is to use each counter's

status output 'directly' as the count input to the next stage, at the same time using it to reset the current stage of the counter. An overflow from the previous counter will then cause the next stage to increment, before resetting the current stage back to zero. As an example, Listing 4.4 shows a two-stage custom timer, this time written for the PIC16F887 microcontroller.

A repeating 1Hz oscillator waveform is used as the input to the first counter, which has a final value of 10. Notice that the counter uses its own status bit to reset itself back to zero. The output of the first counter automatically becomes the input to the next counter (or may be manually read from bit 0 of the CTR register), causing the second counter to be cascaded from the first – this time having a final value of six, and once again using its own status bit as a reset signal. The state of each counter is finally copied to registers PORTC and PORTD, allowing direct viewing on LEDs assumed to be connected to these ports. (Listing 4.4 is particularly suitable for use with the Proteus VSM 16F887 simulation supplied with Part 1.)

The next section considers bidirectional or up/down counters, which tend to be more versatile than their unidirectional counterparts, although quite similar from a programming perspective.

Bi-directional (up/down) counters

Eight bi-directional counters are available, and suitable for applications

```

include "16F887.PLC"           ; Defines PLC instructions

ld      OSCL, 3                 ; Count 1 second pulses
ctr     0, d'10', CTR, 0        ; Count to 10 then reset
ctr     1, d'6', CTR, 1         ; Count to 6 then reset

putr     CTR0, PORTC            ; Copy low byte to Port C
putr     CTR1, PORTD            ; Copy high byte to Port D

endp                             ; Marks end of program

```

Listing 4.4. Creating a multiple-byte custom counter/timer (Lst4_4.asm)

where it is necessary to count values which may either increase or decrease. Consider as an example, a system designed to control entry to a car park, based on the number of spaces available. In this case, the number of spaces available would decrease as cars enter the car park, but would rise as cars leave.

Coding of the bi-directional counter command is similar to its unidirectional counterpart, but with the addition of a direction control input. The ctr_ud command has the following syntax:

```

ctr_ud   CTR_NUMBER[0-7],
         FINAL_VALUE[1-255],
         DIRECTION_REGISTER,
         DIRECTION_BIT[0-7],
         RESET_REGISTER,
         RESET_BIT[0-7]

```

A further difference is the provision of two status bits, compared to the one used by the unidirectional counter. The upper threshold is set when the final value is reached and the lower one by the initial value. These status bits may be read from the appropriate bits of registers CUP (count up status) and CDN (count down status) respectively. (So, for example, the upper and lower status bits for up/down counter five would be available from bits CUP, 5 and CDN, 5 respectively.) Applying a 1 to the Reset input clears the internal count value, at the same time setting the appropriate bit of the CDN register (since the internal count now contains zero).

Current count value

If you need to know the current count value, then this information is available from registers CUD0–

CUD7, where the final digit of the register name is determined by the counter number. (To use the car park spaces analogy again, the ctr_ud command's final value parameter would be used to specify the capacity of the car park, the current count value would be equivalent to the number of cars currently inside the car park, while the appropriate CUP and CDN status bits would indicate that the car park was either full or empty, respectively.)

The example of Listing 4.5 shows an up/down counter configured to count up to ten pulses on Port A bit 0, with initial value and final value status bits available from Port C, bits 1 and 0 respectively.

The program counts pulses applied to bit 0 of Port A, displaying the current count value on LEDs assumed to

cars currently inside the car park, and this would need to be scalable to an arbitrary number of digits, to suit the actual capacity. The number of available spaces would need to be displayed in decimal form, since few motorists can read binary or hexadecimal numbers. Finally, suitable hardware interfacing would be required, including entry/exit sensors, time delays, and switch debounce logic.

In cases like this, where the PLC software doesn't quite do what you might require, then one approach is to consider extending the PLC instruction set by

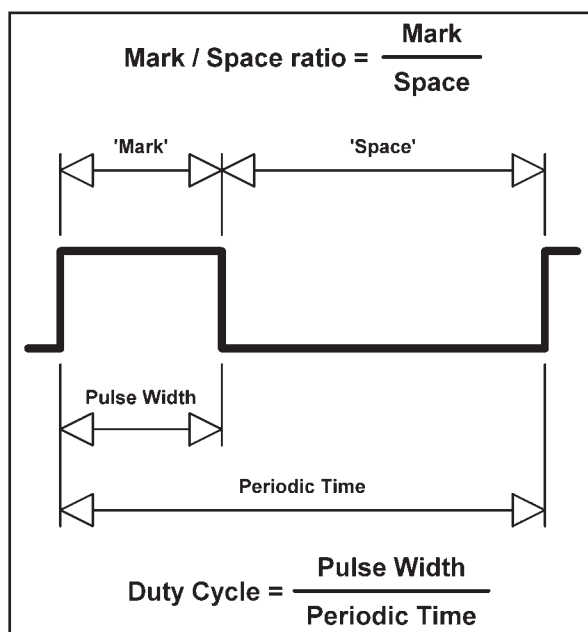


Fig.4.2. Repeating pulse waveforms and their associated parameters

As can be seen, the mark-to-space ratio is defined as the proportion of time the waveform is high, relative to the time the waveform is low. The duty cycle measures the time the waveform is high, relative to the period (time) of the waveform.

The 'duty cycle' approach is used by the PLC software, with pulse width and period time values specified in multiples of 1/500th of a second (ie 2ms). PWM signals may be created, based either

```
include "16F887.PLC"      ; Defines PLC instructions

ld      PORTA, 0           ; Read Port A bit 0
                        ; (clock input to up/down counter)
ctr_ud  0, 0x0A, PORTA, 1, PORTA, 2
                        ; Up/down counter 0,
                        ; Final value = 0x0A (10)
                        ; Direction = Port A bit 1 (1 = Up, 0 = Down)
                        ; Reset = Port A bit 2 (1 = Reset)

ld      CUP, 0             ; Load Up/Down Counter 0 count-up status bit
out     PORTC, 1           ; Output final value reached status

ld      CDN, 0             ; Load Up/Down Counter 0 count-down status bit
out     PORTC, 0           ; Output initial value reached status

putr    CUD0, PORTD        ; Copy current count value to Port D

endp                      ; Marks end of PLC program
```

Listing 4.5. Using a bidirectional counter (Lst4_5.asm)

be connected to Port D. Initially, or following a reset applied to Port A bit 2, the internal count value will be zero, which causes the CDN, 0 status bit to be set (as seen from Port C bit 0). Assuming that the counter is configured to count up, by applying a logic1 to Port A bit 1, then the counter will increment after each clock pulse until the final value is reached, and the CUP, 0 status bit is set (linked to bit 1 of Port C).

Bear in mind that the above car park scenario is used purely as an analogy, and the program would certainly not be suitable in its current form to control a real car park for a number of reasons! To begin with, a display of the number of spaces available would be more useful than the number of

adding custom macros of your own. For example, the addition of a custom decade counter macro with up, down, carry and borrow connections, and capable of being cascaded, would make it easy to display the number of spaces as a decimal number. We'll look at advanced programming concepts, including customisation of the software, in the sixth and final part of the series.

Creating repeating pulses

The PLC software makes it easy to create repeating pulse waveforms of various configurations. Pulse waveforms are commonly defined in terms of their frequency and either their mark-to-space ratio or duty cycle, as illustrated by Fig.4.2.

on directly specified values ('immediate' values), or based on the content of internal registers – with the latter method being more suited to dynamic modification during run-time. Up to four PWM outputs of each type may be created.

The 'pwmi' command produces up to four fixed value (immediate) PWM waveforms. The repeating pulse waveform is driven by an internal clock, which is linked to a 500Hz signal (taken internally from OSCH, 2). The three command arguments are the register number (0-3); the number of 2ms time periods the waveform should be high (1-255); followed by the total number of time periods in the waveform period (1-255). Output

waveforms are available by reading the appropriate bits of the PWMI register. (Thus, for example, the output waveform for the 'pwmi, 2' command may be read from bit 2 of the PWMI register.)

Example of pwmi command

As an example of the pwmi command, the program Listing 4.6 creates four fixed value PWM waveforms, with duty cycles of 20%, 40%, 60% and 80%, and with a base frequency of 50Hz.

Examining the creation of the first waveform in detail, notice that the pwmi, 0 command is supplied with a pulse width of $2 \times 2\text{ms}$ ($2 \times 1/500\text{th}$ of a second), while the period time is defined as $10 \times 2\text{ms}$. Thus, the pulse is high for 4ms out of every 20ms, giving a 20% duty cycle and a base frequency of 50Hz. The waveform is made visible by copying the output bit from PWMI, 0 to bit 0 of Port D. Fig.4.3 shows the output produced by the program, running on a PICKit 2 Debug Express unit.

Although it is easy to create fixed duty cycle waveforms, the ability

The 'pwmr' command produces up to four 'variable' or register-based PWM waveforms. The three arguments supplied to the pwmr command are the register_number (0-3), the register containing the number of pulses the waveform should be high (0-255), followed by the register holding the total number of pulses in the waveform (1-255).

A simple example is given in Listing 4.7, which first loads the desired duty cycle parameter values into a pair of registers, and then uses the pwmr command to create a 20% duty cycle waveform.

The real power of this method is the

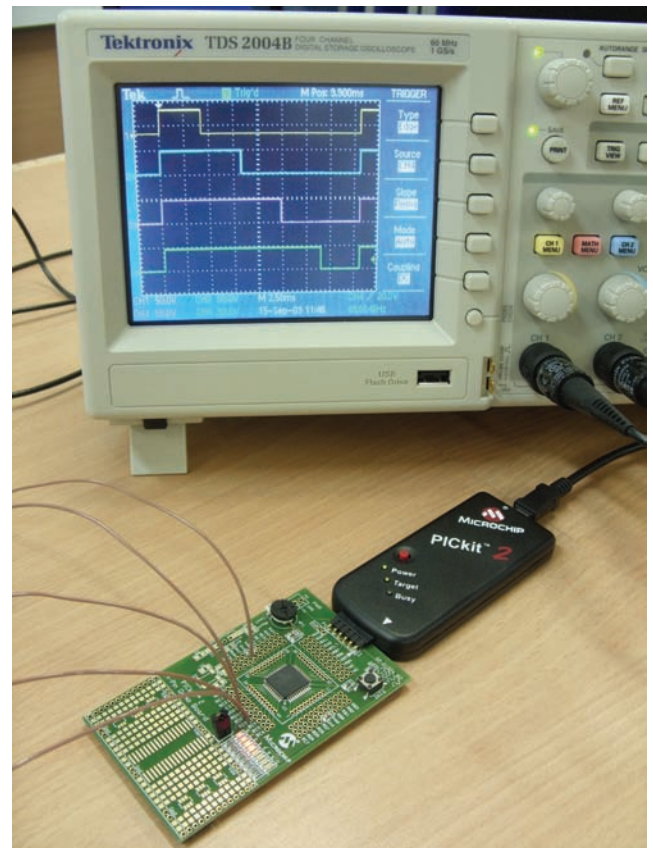


Fig.4.3. Creation of fixed duty cycle waveforms using the PICKit 2 Debug Express unit.

```
include "16F887.PLC"           ; Defines PLC instructions

pwmi    0, d'02', d'10'         ; 20% duty cycle on PWMI, 0
pwmi    1, d'04', d'10'         ; 40% duty cycle on PWMI, 1
pwmi    2, d'06', d'10'         ; 60% duty cycle on PWMI, 2
pwmi    3, d'08', d'10'         ; 80% duty cycle on PWMI, 3

ld      PWMI, 0                 ; Load PWMI, 0 waveform (20%)
out     PORTD, 0                 ; Output to Port D bit 0

ld      PWMI, 1                 ; Load PWMI, 1 waveform (40%)
out     PORTD, 1                 ; Output to Port D bit 1

ld      PWMI, 2                 ; Load PWMI, 2 waveform (60%)
out     PORTD, 2                 ; Output to Port D bit 2

ld      PWMI, 3                 ; Load PWMI, 3 waveform (80%)
out     PORTD, 3                 ; Output to Port D bit 3

endp                             ; Marks end of PLC program
```

Listing 4.6. Creating fixed duty cycle waveforms (Lst4_6.asm)

to dynamically vary the duty cycle at run time can be more useful when developing applications – with potential scenarios including DC motor speed control, lamp dimmer circuits, or servo-based position control systems.

```
include "16F627.PLC"           ; Defines PLC instructions
puti    d'02', AUX0             ; Put 2 into register AUX0
puti    d'10', AUX1             ; Put 10 into register AUX1
pwmr    0, AUX0, AUX1           ; Create PWM waveform based on AUX0/AUX1

ld      PWMR, 0                 ; Load PWMR, 0 output bit
out     PORTB, 0                 ; Send PWM signal to Port B bit 0

endp                             ; Marks end of PLC program
```

Listing 4.7. Creating a register-based PWM waveform (Lst4_7.asm)

capacity to modify the content of the registers used by the pwmr command at run-time, hence allowing real time control of the pulse width and period time respectively. As an example of this technique, Listing 4.8 shows the running count value of an up/down counter, being used to control the pulse width of a PWM waveform.

Operation of the program is logically divided into three sections, with the first initialising the up/down counter, the second configuring the PWM signal, and the third actually making the waveform visible on an output port.

Section 1: Applying an input to either bit 0 or bit 1 of Port A will enable the counter, but Port A bit 1 also serves to control the direction of the counter (1 = up/0 = down). Thus the former causes the counter to decrement, while

```
include "16F627.PLC" ; Defines PLC instructions

ld      PORTA, 0      ; First section - configure up/down counter
or      PORTA, 1      ; Read Port A bit 0 (Slower input)
and     OSCL, 1       ; OR with Port A bit 1 (Faster input)
and     OSCL, 1       ; Clock input to up/down counter
ctr_ud  0, d'31', PORTA, 1, PORTA, 2
                        ; Up/down counter 0, final value = 31
                        ; Direction = Port A bit 1
                        ; Reset = Port A bit 2
                        ; Up/down counter working register = CUD0

puti    d'32', AUX1   ; Second section - configure PWM signal
pwmr    0, CUD0, AUX1 ; Put 32 into register AUX1 (= period)
                        ; Create PWM waveform based on CUD0 and AUX1

ld      PWMR, 0       ; Third section - display PWM waveform
out     PORTB, 0      ; Load PWM status bit
                        ; Output waveform to bit 0 of Port B

endp      ; Marks end of PLC program
```

Listing 4.8. Varying pulse width by using a bidirectional counter (Lst4_8.asm)

the latter makes it increment, with the rate of change controlled by ANDing the combined signal with OSCL, 1 (a 4Hz square wave signal).

Section 2: The up/down counter is configured to count up to a maximum value of 31, with the running count stored in register CUD 0. This value is then used by the pwmr command as the pulse width value of a variable PWM waveform, with a fixed period time (32 pulses) obtained from register AUX1. Thus, the maximum duty cycle will be 31/32 or 96.9%, with a period time of 64ms (32 × 2ms)

Section 3: The PWM status bit is read from bit 0 of register PWMR and copied to bit 0 of output Port B.

Linking an up/down counter to another electronic sub-system (a PWM waveform generator in this case) is a powerful technique, and may be used as a building block in a wide variety of electronic systems. This concept will be explored further in Part 6, where a number of custom macros will be developed, based on the general theme of 'code conversion', allowing direct connection of counters to devices including stepper motors, Gray-coded discs and seven-segment displays.

Summary

Part 4 of the series has continued the tour of sequential logic features of the PLC software, introducing counters and

the generation of PWM waveforms. A wide variety of systems may now be developed, ranging from burglar alarms to motor speed controllers – and using only a few lines of code in each case.

Next Month

While the development of software using a ladder logic approach is clearly useful with microcontrollers, any practical system is likely to contain a combination of hardware and software. Essential concepts related to hardware interfacing techniques will, therefore, be considered in the

next and penultimate part, allowing the PIC micro to be linked to a wide variety of hardware, including switches, LEDs, transistors, relays, motors, solenoids and opto-couplers.

Further byte-oriented capabilities of the software will be discussed, including the (surprisingly powerful) sequencer command. Byte-oriented logical and arithmetic capabilities will also be introduced, while other byte-oriented capabilities will be briefly recapped, including byte comparison and byte transfer commands.

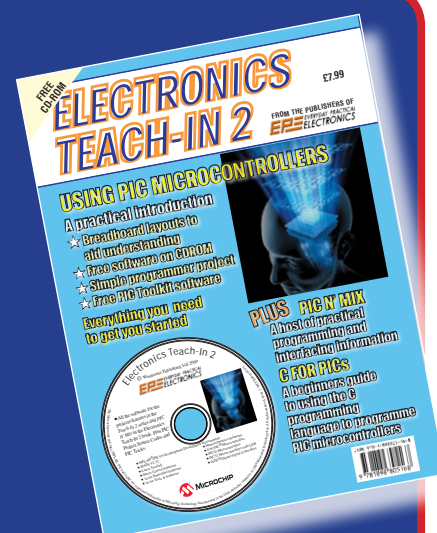
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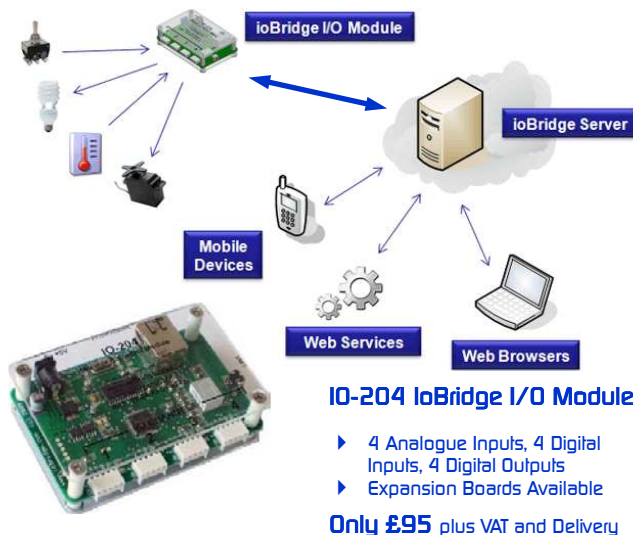
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Commercial Video Modules

We return this month to the topic of generating video from a PIC. In our previous articles, we have discussed the generation of composite video for driving televisions, but overlooked LCD monitors. These days, LCD monitors are small and light weight, offer very good quality pictures and are very cheap – especially the relatively low resolution ones that are consider ‘old technology’.

Displays with resolutions of 1024×768 pixels can be purchased for a few pounds on eBay now, and yet they would make fantastic screens for hobby projects. Needless to say, we cannot resist the temptation to try driving one from a PIC, and possibly generating a bit of colour!

LCD displays support the VGA range of video formats rather than composite video, which is good news for us since VGA signals are actually simpler to generate, although there are other challenges to overcome. First though, a bit of history.

VGA standard

The VGA standard was introduced by IBM in 1987 for its ill-fated PS/2 PC, a product designed to win back the PC market that IBM lost to the PC clone manufacturers. The previous five years had seen a remarkable growth in display formats: MDA monochrome graphics, CGA colour, then EGA to name but a few.

Each new standard gave significant improvements on the previous generation, but annoyingly required completely different monitors. VGA was no different, but by providing 640×400 pixels with 16 colours, it was adopted as the standard display format for new software applications and games. The PC clone manufacturers soon came out with compatible cards, and even more quickly enhanced the standard with a range of ever-increasing resolutions – 640×480 , 800×600 , 1024×768 .

The resolution game continues today. An informal standard called ‘Super VGA or SVGA’ came into place describing the wide range of resolution and colour depth variation. This time, however, the multitude of different resolutions were all compatible with each other, and a monitor (CRT in those days, of course) could support many if not all resolutions below its maximum capability.

Unlike the PAL composite video signal, the VGA standard has the vertical sync, horizontal sync, and three primary colour signals (Red, Green, Blue) all appearing on their own wires. The sync signals became digital, while the colour signals are analogue between 0V and 0.7V.

Fig.1 shows the signal timings for an individual line and an individual screen, or frame, at a resolution of 640×480 . Unlike PAL, there is no interlacing of frames so there are no special signals to indicate ‘first frame’.

In theory, that doesn’t sound like an impossible job for a high-end microcontroller.

Display resolution

Now we are interested in driving an LCD rather than a CRT monitor, and there is one issue we need to bear in mind. LCDs have *fixed* display resolutions. They are constructed as an array of physical pixels. If you try to drive an LCD monitor who’s physical resolution is 1024×768 with a signal for 640×480 pixels, the monitor ‘adjusts’ the data to match, and rarely does a good job of it. So, if you have a vertical line one pixel wide, the display may show it as two pixels wide, depending on where you place it on the display. It doesn’t look great. This means we have to be careful about our choice of output resolution, or about our choice of monitor.

The next problem is the sheer number of pixels we have available. Even at 800×600 , there are 480,000 pixels. That equates to 480KB if we were to store each pixel in a single byte (to store its colour value.) Fortunately, if we choose to display text rather than allow full graphics then there are tricks we can use to get round this problem.

Our previous video designs have relied on the SPI serial port peripheral to provide a fast and accurate video signal. The SPI interface is, of course, digital and can only provide an on/off video level – hence the black and white display. This solution is clearly not going to adapt easily to colour video generation, where we want a number of data bits per pixel, not just one!

Data bits

The absolute minimum acceptable number of data bits per pixel is three – one per colour. This suggests one possible solution, which is three processors synchronised together, each one driving a single colour, but that doesn’t yield a particularly acceptable return on the investment. We would like at least 64 colours, which requires two data bits per colour. And as six bits fits nicely into a byte (leaving the other two bits to drive vertical and horizontal sync lines) it seems an efficient option. This would require some kind of parallel port running at high speed. The PIC24 and PIC32 processor families come equipped with advanced parallel port peripherals, so maybe they could be up to the task.

There is, however, an alternative (potential) solution. An unusual route for *PIC n’ Mix* – using a non-Microchip processor, the Propeller Chip from Parallax, the people who brought us the Basic Stamp (see the review of their Propeller Demo Board on page 20). The Propeller is a unique device;

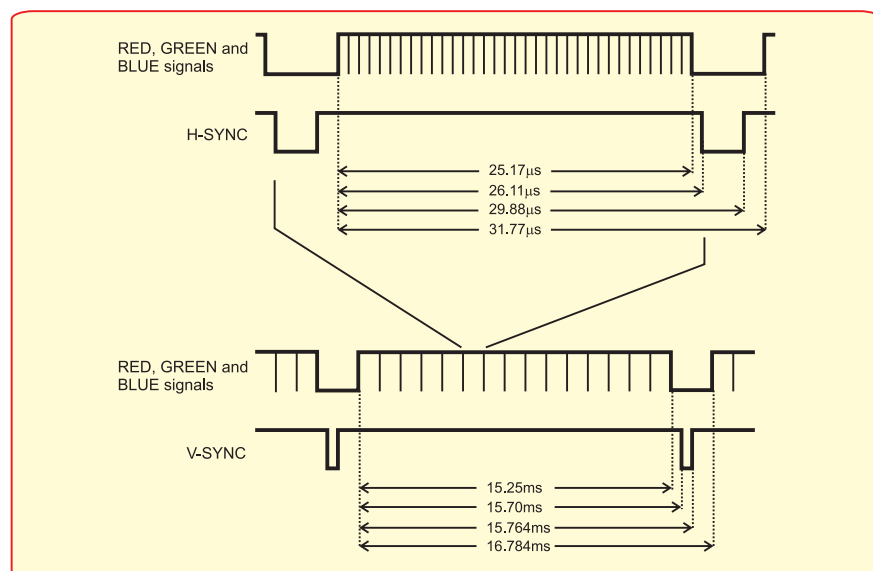
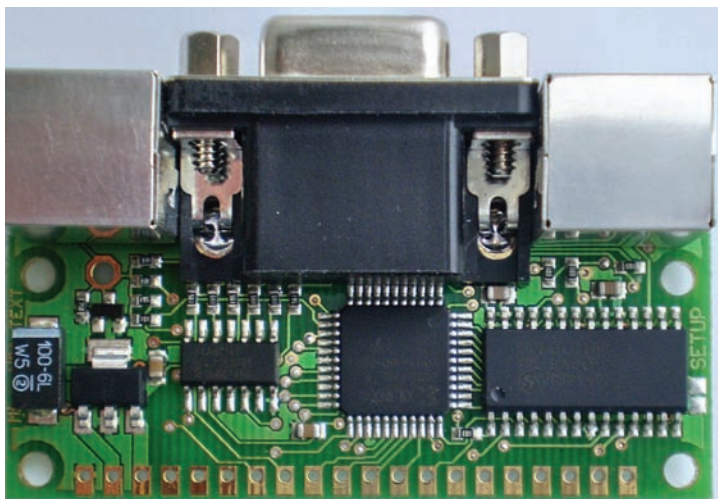


Fig.1. The VGA signal timings for an individual line and individual screen, or frame, at a resolution of 640×480



The μ VGA module



The μ VGA module output

it contains eight, 32-bit processors and yet is available in an easy-to-use 40-pin DIL package, and at low cost. The processor contains special hardware specifically intended to ease the generation of video, so this device deserves a look.

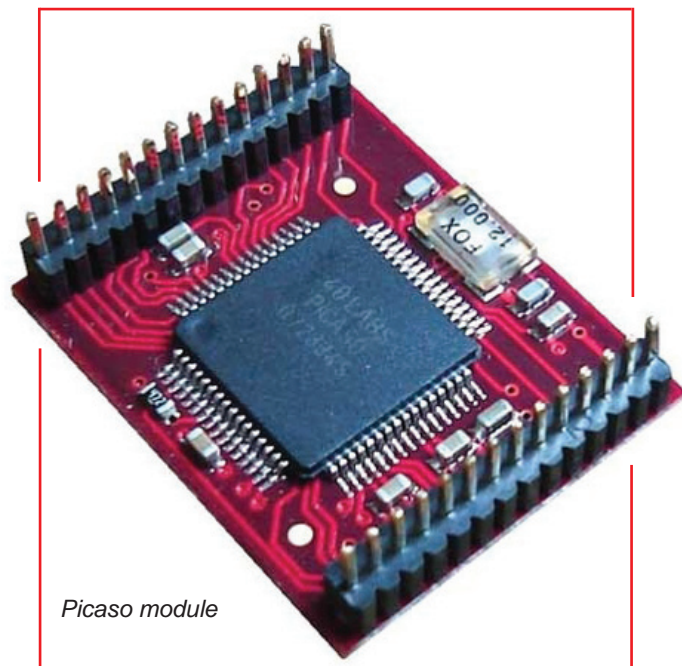
As you can see, there are many issues to solve and several possible routes to take, so lots to think about. For now, let's take a look at two commercial products that do something similar to what we are trying to achieve.

Graphics module

The first is ' μ VGA-Picasso-MD1', a tiny VGA controller module from 4D Systems and available from distributors like Farnell for about £40. It runs at 3V and draws just 90mA, but can deliver 620×420 resolution with 256 colours.

A simple TTL-level serial interface connects the module to your microcontroller, and a novel SPI interface enables the module to interface to an SD Media card, on which images can be stored and loaded directly into the module at high speed, reducing the load on the processor interface. The module requires an external digital-to-analogue converter to drive an LCD monitor, but a simple reference design consisting of some 27 resistors and six off-the-shelf transistors is supplied.

Even the tiniest microcontroller can drive this display using a series of simple to use commands. There is enough video memory on board for two complete screens, so the technique of double-buffering, where you



Picasso module

write to one area of memory while the other is being displayed, enables you to provide smooth screen updates. The obvious advantage of this module is that it can display both text and graphics, although as we were unable to get our hands on one of these in time for the article we were un-

able to assess the speed at which a graphics display could be updated.

Text module

The 'Micro VGA' from SeCons is an interesting compliment to the Picasso module. Again it is a small, self-contained module, but it

provides only a colour text interface rather than full graphics. It drives a display at 800×600 pixel resolution and uses an RS232 interface to receive both character data to display and various commands to control the cursor position, colour settings etc. A particularly interesting feature of this module (apart from the fact that it uses a PIC microcontroller!) is that it also provides a PS/2 keyboard interface. Coupled with an LCD display, this module performs the functions of a complete colour text terminal. Once again, this is a very low-powered device, so it makes an interesting alternative to using a PC.

With both these boards consuming about 300mW compared to 300W from a standard PC, the power savings could be quite substantial. Plus, it would do your 'green' credentials no harm at all!

This move towards low power computing is quite interesting, and we hope to bring you our own low power LCD controller soon.

Competition Results

Finally, this month, we reveal the winner of our 'XGS PIC 16-bit' Game Development System. Thank you to everyone who has contacted us to detail their designs and share their ideas. Our winner is **Mike**

Boyd for his custom built terminal, made from the guts of an old five-inch television, some bent aluminium and a keyboard salvaged from a recycling centre. Well done Mike, your XGS system is on its way!



More on filter circuits

IN the July to September 2009 issues of *EPE*, *Circuit Surgery* ran a three-part article on active filter design following a question from **Paul Goodson**, posted on the *EPE Chat Zone* (chatzones.co.uk). This produced a couple of further questions on poles and zeros and the time domain response of filters (Oct and Nov '09). The latter was prompted by a question from **Nagi Saad** on why time domain response was important in filter design. **Chris Wood** wrote to us from Essex with an example of a time domain response problem in a commercial design.

Response time

Your article on time domain response, in *EPE* Nov '09 issue, reminded me of a problem that arose when my company took advantage of the developments in IC technology to update their product line in the 1970s.

The company was *Cossor Electronics*, later to become *Raytheon Systems Ltd*. The product was its secondary surveillance radar interrogator, used for air traffic control. Prior to the development by *Plessey* of a logarithmic IF (intermediate frequency) amplifier, the receivers in these devices consisted of a mixer to convert the 1090MHz pulsed carrier aircraft reply to 60MHz IF, followed by a bandpass filter (BW (bandwidth) about 10MHz), then a low-noise amplifier and video detector. AGC (automatic gain control) was achieved with a PIN diode swept attenuator before the mixer, ensuring that the overall gain started low and gradually increased for signals from greater distances.

With the advent of *Plessey's* logarithmic IF amplifier, it became possible to dispense with the PIN diode attenuator and redesign the receiver with a low gain, linear, post-mixer amplifier, then the bandpass filter and then several stages of logarithmic devices to achieve a dynamic range of 80 to 90dB. What was not realised beforehand, because it was hidden by the relatively low dynamic range of the linear amplifier, was that the bandpass filter continued to 'ring' due to the pulsed carrier signal.

Because of the high dynamic range achieved with the logarithmic IF amplifier, this appeared as a slowly decaying ramp at the trailing edge of each pulse, including several 'humps' on the decaying edge. This phenomenon made it difficult to measure the true received pulse width and pulse separation, and hence made the system worse, not better.

Many exotic filter designs were tried, with the best consisting of a Bessel response down to 9dB, and a Butterworth response below that. Fortunately, this change made all the difference and the system continues to use this design to this day.

We thank Chris for his interesting letter, which reinforces the importance of filter time domain response discussed in the November 2009 issue.

Chris's story is also interesting because it demonstrates that improving one part of a circuit can make the whole thing fail. I have encountered other issues like this in commercial designs, particularly where products are in use for many years.

In one case, the speed of some logic gates increased significantly as technology developed, causing problems for newly manufactured versions of a long-standing design. The manufacturers of the gates specified a minimum speed, but never a maximum one, so the newer, faster gates were not out of specification, and the system manufacturer could not blame the supplier of the gates.

Back to basics

Returning to our filters theme, we have received another letter on this topic, in this case taking us back to some of the basics of frequency-dependent circuits. The original articles discussed active filters

and their many possible configurations; **Mr Walker** of North Lincolnshire writes to ask about the basic properties of the resistors and capacitors used to set filters' characteristics.

I really enjoyed the articles on filters, particularly poles and zeros (Oct '09) – all extremely well described.

I have a couple of questions regarding filters:

(i) In *EPE* Aug '06, page 48, for Fig.10.14 (Teach-in 2006, part 10) it states that, 'The lower cut-off frequency is determined by the value of the input capacitor, *C1*, and input resistance *R1*', and '... the upper cut-off frequency will be determined by the feedback capacitor, *C2*, and feedback resistor *R2*, ...'. My question is: How does a capacitor act as a filter?

(ii) In *EPE* Oct '09, page 55, Fig.1 (Circuit Surgery) shows a basic RC filter. My question: How does a resistor act as a filter?

These two examples (see below left) show an active (Fig.1.) and passive (Fig.2.) filter. Active filters use amplifiers such as op amps or transistors to provide improved performance over passive filters, but in both cases it is not just a resistor (*R*) or a capacitor (*C*) on its own that determines the filter's characteristic, but it's the combination of the two that matters, hence the term 'RC circuit'. Similarly, inductors (*L*) can also be used to make filter circuits; again it is the combinations that provide the filtering operations: *RL*, *LC* and *RLC* circuits can act as filters.

To explore this in more depth, it is worth looking at the three basic components on their own, in particular how their response to an applied voltage varies with frequency. Fig.3 to Fig.8 show schematics and waveforms from LTSpice (free download from Linear Technology, see www.linear.com/designtools/software/). Shown are the voltage across (green waveform), and current through (blue waveform) a resistor, capacitor and inductor. The inductor is driven by a current source because this is easier for the simulator in this situation, but the graph still shows the voltage and current relationships in the same way. The component values were chosen to give approximately the same current and voltage of around 1V peak-to-peak (ptp) and 30mA. All waveforms are at 5kHz.

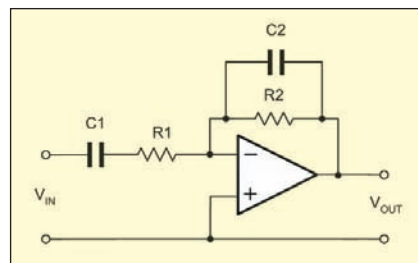


Fig.1. An inverting amplifier with capacitors to limit both the low and the high frequency response (*EPE* Aug '06, P48)

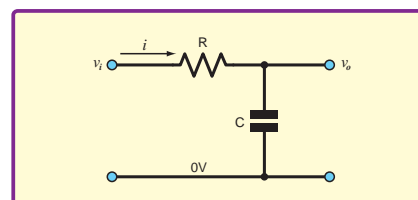


Fig.2. A basic RC low-pass filter (*EPE* Oct '09)

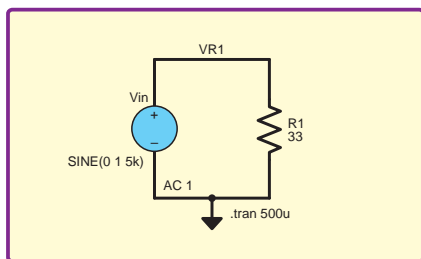


Fig.3. Resistor circuit

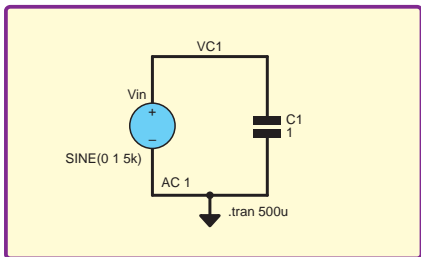


Fig.5. Capacitor circuit

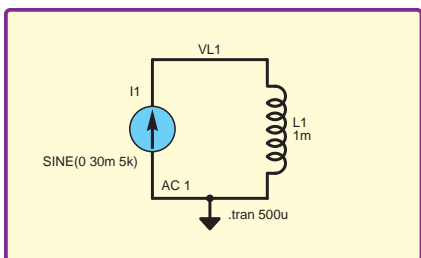


Fig.7. Inductor circuit

Special relationship

Of particular interest in Figs.4, 6, and 8 is the time relationship between the current and voltage. For a resistor (Fig.4) the current follows the voltage directly – as the voltage increases the current also increases. The voltage and current waveforms are *in phase*.

The specific relationship between current and voltage at any instant for a resistor is determined by the resistance, R .

Resistor voltage = $R \times$ (current through resistor)

In general, the current-voltage equation describing the behaviour of an electronic component is known as its characteristic equation. In this case, of course, it is known as Ohm's law, and we usually write:

$$V = IR$$

For the capacitor (Fig.6), the current waveform is a quarter of a waveform cycle later than the voltage; for example, the voltage peaks at $200\mu\text{s}$, but the current peaks $50\mu\text{s}$ later at $250\mu\text{s}$, (a full cycle is $200\mu\text{s}$). Waveform cycles are usually described in angular form (which is independent of the actual time involved), so a quarter cycle is 90° . Here the current has a $+90^\circ$ phase shift with respect to the current.

Looking at the capacitor waveforms in another way, we see that the peak positive current corresponds to the point at which the voltage is changing fastest (as it passes through zero). Furthermore, the current is zero at the point where the voltage is not changing – the instants at the top and bottom

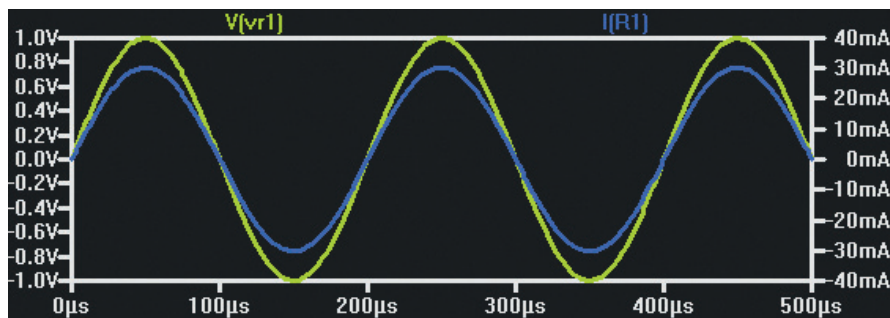


Fig.4. Voltage and current waveforms for resistor

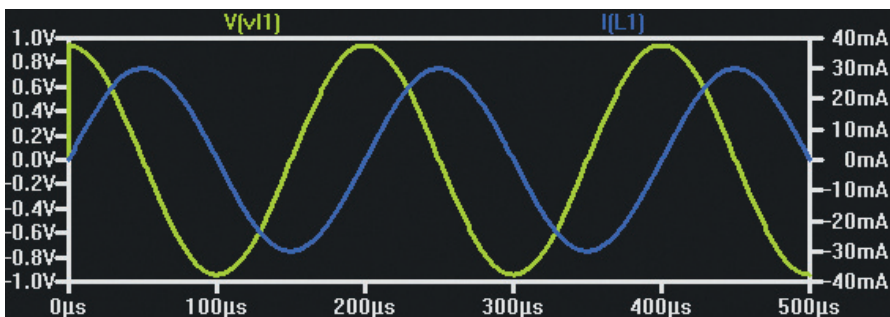


Fig.6. Voltage and current waveforms for capacitor

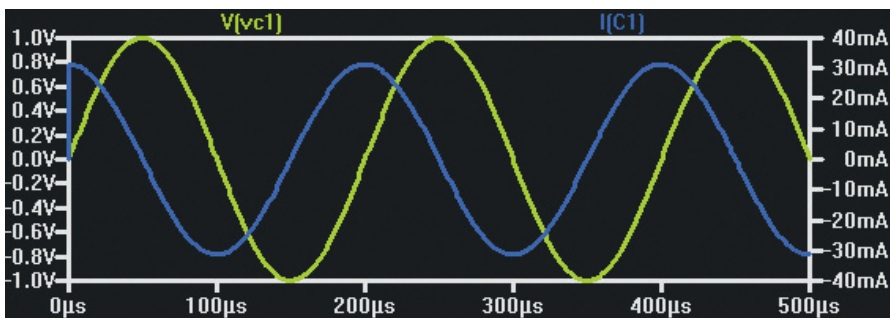


Fig.8. Voltage and current waveforms for inductor

of the peaks of the voltage waveform. In fact, the value of capacitance of a capacitor, C , relates the rate of change of voltage across it, to the current through it:

Capacitor current = $C \times$ (Rate of change of capacitor voltage)

Rate of change

To express 'rate of change' in more formal mathematical terms we need calculus, in which we write rate of change as dV/dt ; here dV represents the amount the voltage changes in an infinitesimally small amount of time dt . dV/dt is called a *derivative*. The characteristic equation of the capacitor is:

$$I = C \frac{dV}{dt}$$

However, we will not be using calculus in this article; it is sufficient to note the importance of rate of change in the current to voltage relationship.

For the inductor (Fig.8), the waveforms are similar to capacitor, except the current phase shift is in the opposite direction; it is -90° . The voltage to current relationship is also 'the other way round', specifically for an inductor of value L

Inductor voltage = $-L \times$ (Rate of change of inductor current)

Again, we have a rate of change in the relationship and a derivative in the characteristic equation:

$$V = -L \frac{dI}{dt}$$

Looking at the three characteristic equations, we see that for the inductor and capacitor 'rate of change' is important, whereas for the resistor it does not come into the equation. For a given waveform shape (eg, a sine wave) it is intuitive that if we increase the frequency, the rate of change increases in those parts of the waveform that represent a changing voltage or current. From this, it follows that the current to voltage relationship for capacitors and inductors change with frequency, but for resistors it does not.

For capacitors and inductors there is a more general form of Ohm's law, which we write as:

$$V = IZ$$

in which all three quantities are *complex numbers* and Z is the *impedance* of the component. Complex numbers have two dimensions, which allows them to account for both the phase and amplitude of a signal (something which Figs.4, 6 and 8 show is important in the difference between inductors, capacitors and resistors). We discussed complex numbers in more detail in *Circuit Surgery* Oct'09.

For a resistor, the impedance is equal to the resistance. For any impedance, we can find a 'normal' number which represents the size of the impedance, ignoring the phase. This is known as the magnitude of the impedance, and it is what we will refer to in the rest of this article. The magnitude of impedance of a capacitor at frequency f is $1/2\pi fC$, and for an inductor it is $2\pi fL$.

By definition

Given that a filter is by definition a frequency-dependent circuit, we can conclude (in answer to Mr Walker's question) that a resistor on its own will never act as a filter, but a capacitor or inductor may do so. We can use AC analysis in LTSpice to plot the variation of magnitude of impedance (effective resistance) with frequency, specifically the magnitude of the voltage divided by the current in the three circuits shown in Figs.3, 5 and 7. This is shown in Fig.9 to Fig.11 respectively. We use an 'expression plot' in LTSpice and manually change the axes to linear from the default logarithmic plots used for frequency responses.

The three figures show impedance variation from 1kHz to 10kHz. In the centre of this range, at 5kHz, we have the situation where all three impedances are around 30Ω ; corresponding to the situations plotted in Figs.4, 6, and 8. From these plots we see the impedance of the capacitor decreases with frequency, and that of the inductor increases.

The capacitor and inductor curves in Fig.10 and Fig.11 do not, at first sight, appear to be very closely related. However, if we plot $1/\text{impedance}$, that is the *admittance*, for the inductor we can see the inductor actually has a similar, but 'other way round' response to the capacitor. The plot is shown in Fig.12. Admittance is measured in Ω^{-1} or siemen. A resistance (impedance) of 40Ω is a conductance (admittance) of $25\text{m}\Omega^{-1}$ or 25mS .

In the extreme, a capacitor is an open circuit at very low frequencies and a short circuit at very high frequencies. For the inductor, it is the other way round; inductors are short circuits at very low frequencies, and open circuits at very high frequencies. Using these extremes can often provide a quick and easy insight into how a circuit will behave at the upper or lower limits of its frequency range, without requiring any detailed analysis.

Acting filter

Mr Walker asks how a capacitor acts as a filter. There are situations where inductors or capacitors are used on their own for filtering or similar purposes. Supply decoupling capacitors provide a low impedance path from supply to ground for AC signals (ripple and noise on the supply), but represent very high impedance (open circuit) to the DC. Capacitors used to couple circuits (eg, from one amplifier to another) block DC (offsets and bias), but let the AC signal through.

Inductors in series with signal cables are used to block high frequency signals, which otherwise might cause electromagnetic interference. They are often implemented using ferrite beads around a cable or wire.

When we think of a filter circuit, it is usually of something with an input signal (voltage) and an output signal (voltage). This does not really apply to the circuits in Figs.3, 5 and 7. The simplest way to obtain an output voltage dependent on the characteristics of basic components is to use a potential divider circuit, as shown in Fig.13.

Given that we have already seen that the characteristics of resistors do not change with frequency, it follows that the output voltage on Fig.1 does not change with frequency and the circuit is not a filter. If the two resistors are equal (as shown on the schematic in Fig.13) the output voltage is half the input voltage for all frequencies. The current through the two resistors also does not change with frequency.

Divided potential

If we make a potential divider with two capacitors, as shown in Fig.14, we might be tempted to think that the voltage changes with frequency. However, it does not because both capacitors change in the same proportion as the frequency changes. Thus they continue to divide the input voltage in the same way. There is a difference from Fig.13 however; unlike the resistors, the current through the capacitors does change with frequency, increasing at higher frequencies as their impedance decreases.

Two resistors or two capacitors in a potential divider do not make a filter, but a combination of a resistor and a capacitor

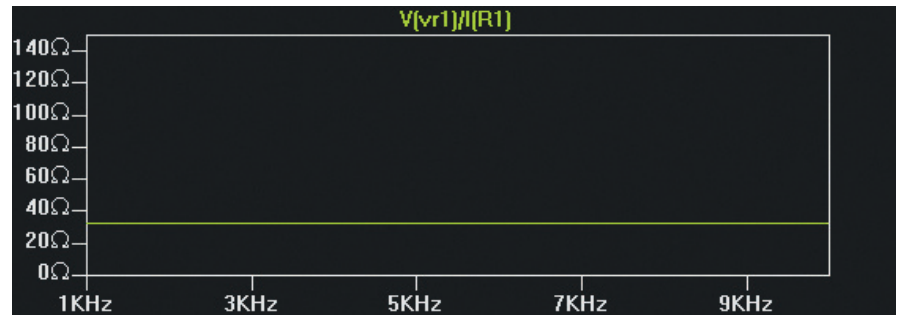


Fig.9. Resistor impedance variation with frequency

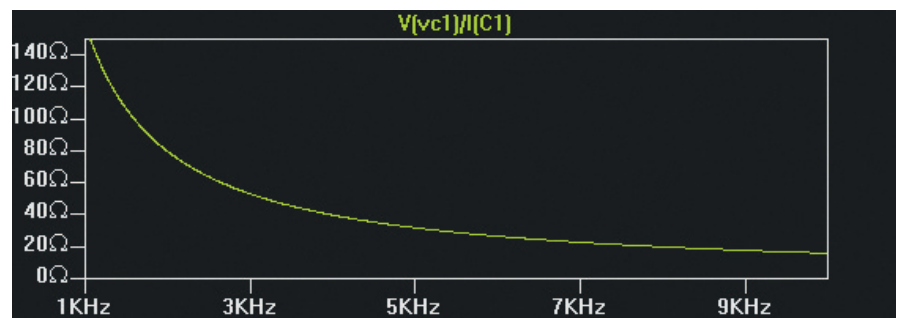


Fig.10. Capacitor impedance variation with frequency

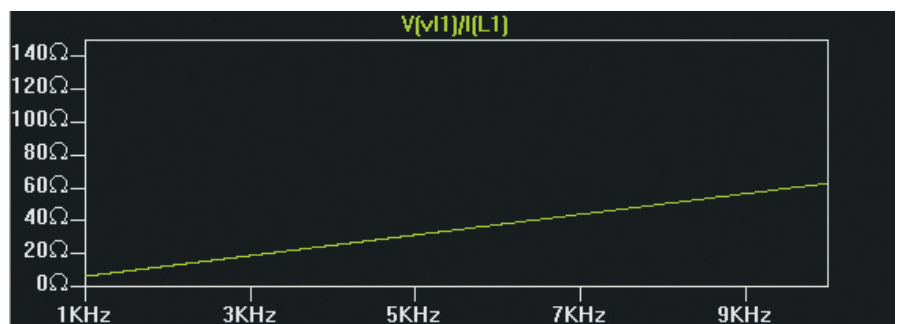


Fig.11. Inductor impedance variation with frequency

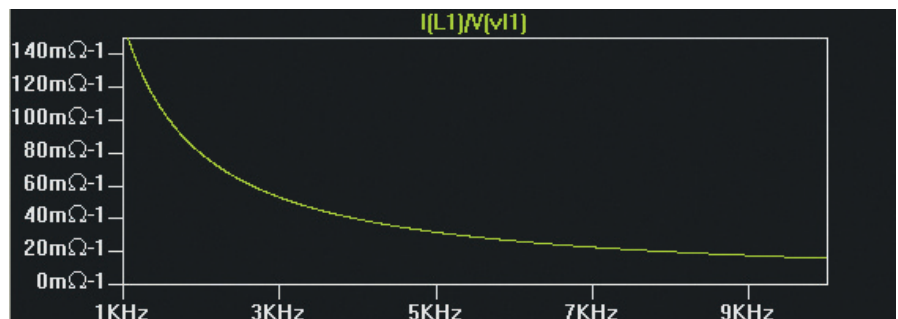


Fig.12. Inductor admittance ($1/\text{impedance}$) variation with frequency. Compare this with the capacitance impedance curve in Fig.10

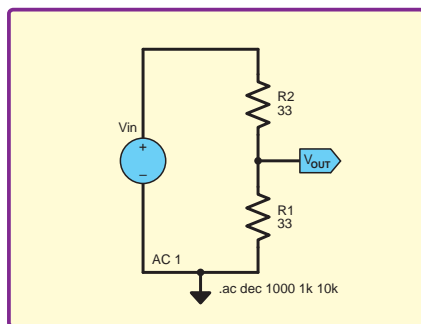


Fig.13. Resistor potential divider. The current through the resistors and the output voltage do not change with frequency

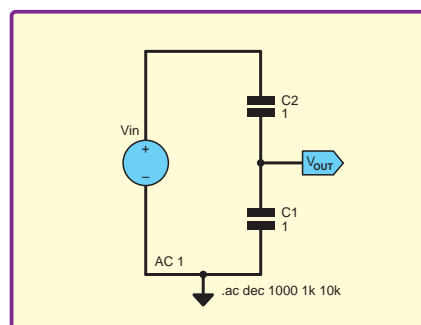


Fig.14. Capacitor potential divider. The current through the capacitors increases with increasing frequency, but the output voltage does not change

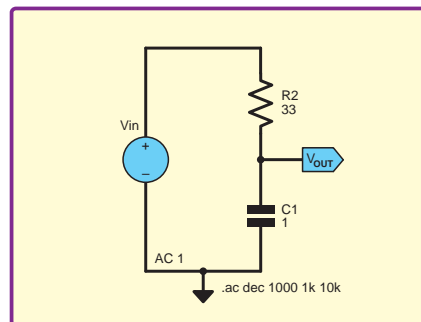


Fig.15. Low-pass RC filter. The current through the circuit increases with increasing frequency and the output voltage decreases

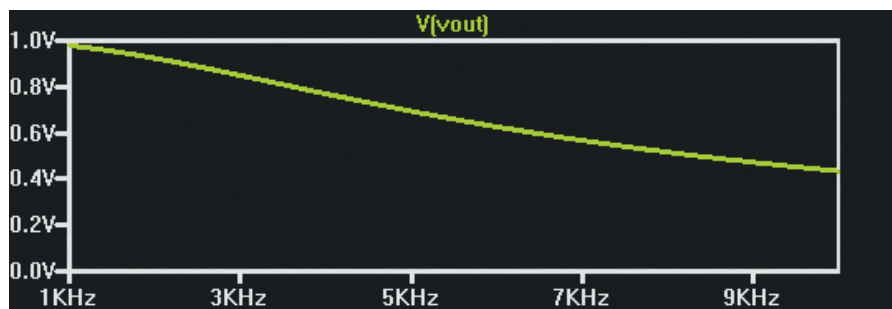


Fig.16. Output voltage variation with frequency for the low-pass RC filter shown in Fig.15

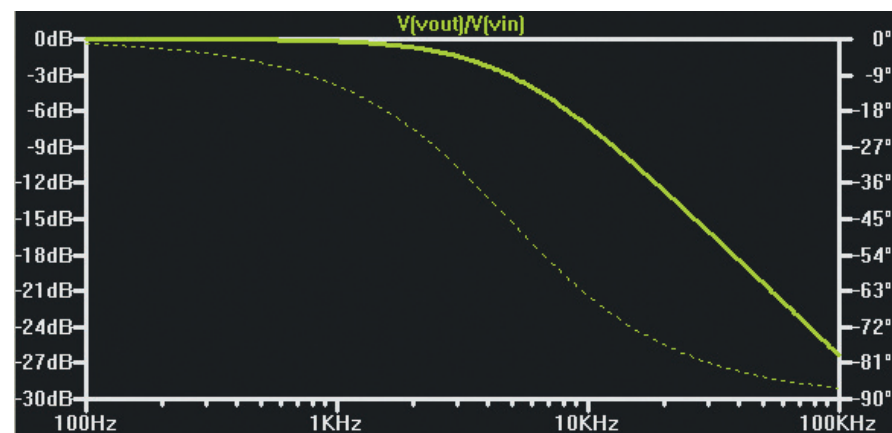


Fig.17. Conventional frequency response plot for the RC filter shown in Fig.15

does. Fig.15 shows the same potential divider arrangement as Fig.13 and Fig.14, but with a resistor and a capacitor. The resistor's impedance does not change with frequency, but as frequency increases the capacitor's impedance decreases, and hence a reducing proportion of the output voltage will appear across it. The output voltage decreases with increasing frequency – the circuit is a low-pass filter. If we swap the resistor and capacitor around in Fig.15, we get a high-pass filter.

The output voltage for Fig.15 over the same 1kHz to 10kHz range used in the previous plots is shown in Fig.16. The output voltage at 5kHz is not 0.5V, as might be expected knowing the resistor

and capacitor impedances are similar at this frequency, because the magnitude of the combined impedances of C1 and R2 is not simply the sum of their individual magnitudes. A full analysis requires complex numbers.

Fig.16 is not a conventional way to graph the frequency response of a filter; so Fig.17 shows a more familiar plot, this time over a wider frequency range (100Hz to 10kHz) and with a logarithmic frequency scale. The output (continuous line) is expressed as the attenuation (ratio of V_{out} to V_{in}) expressed in decibels, also a logarithmic scale. The graph in Fig.17 also shows the phase shift between the input and output voltage (dotted line).

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Max's Cool Beans

By Max The Magnificent

Brain boggling!

Way back in the mists of time, when I was a young lad of around 14 years of age living in Sheffield, I used to eagerly await the arrival of the monthly issue of *Practical Electronics* (one of the hobby electronics magazines that eventually grew into today's illustrious *EPE* publication).

I started off with the simple *Take Twenty* projects (less than twenty components and less than twenty shillings) and proceeded to annoy my mother with a variety of interesting visual and audible 'effects'. Over time, I progressed to more ambitious projects. One I recall in particular, was a biofeedback *Brainwave Amplifier*. The project used a board with an extremely sensitive pre-amplifier and filters and 'stuff' that could pick up one's brainwaves, filter out a particular frequency associated with being in a relaxed state (I think it was the alpha waves – 8Hz to 14Hz), and use these to trigger a 'pink-noise' generator.

Sadly, my little beauty never worked. I'm sure I made some simple mistake, but I didn't have much in the way of test equipment and – at that time – I had no skills with regard to isolating and debugging problems in electronic systems. On the other hand, this project wasn't a complete failure, because it ended up earning me my degree and – without doubt – getting me where I am today.

What? You want to hear more? Oh well, only if you insist. I'm afraid that when I was 18 and taking my 'A' levels, I was a little naughty, and attended a party the night before my maths exam. It was a great party – so good in fact that the exam itself remains something of a blur. The end result was that although I did OK in physics and chemistry, I didn't actually have a high enough grade in maths to get me into college. Bummer.

Some weirdo

So I started interviewing for jobs. Then one day a letter arrived purporting to be from the Electronics Department at Sheffield Polytechnic (now Sheffield Hallam University) inviting me to come down for an interview. So I put on my best (only) suit and toddled down town on the appointed day. I eventually located the electronics department, where the office manager asked me what I wanted. I showed her my letter, and she emitted a groan. She explained that some weirdo had been going through the 'A' level results, finding folks who had just missed qualifying, and sending them letters inviting them to non-existent interviews.

Well, in this case I had the last laugh, because the office manager said she was sick and tired of sending folks away, so she was going to send me into the head of department for an interview. In turn, he asked me if I'd ever built anything in electronics (I later discovered that many students in my course had never even picked up a soldering iron). So I proceeded to regale him with the description of my brainwave amplifier (leaving out any boring details, like the fact I'd never actually got it to work), and he was so impressed that he somehow managed to squeeze me into the course. It's a funny old world when you come to think about it.

But that's not what I wanted to tell you about. The reason for these meandering musings is that I just took delivery of one of the first toys to be controlled by brainwaves. This is seriously cool. I'm sure that we've all watched the *Star Wars* films over and over again (tell me I'm not alone). Throughout the series,

there are numerous occasions when Luke Skywalker is honing his skills as a Jedi Knight. I know that when I saw him controlling things with his mind, I thought: 'I'd really like to be able to do something like that!' Well, now I can....

May the force be with you!

This 'Star Wars Force Trainer' features a headset that measures your brainwaves and wirelessly transmits the results to a base station that includes a ping-pong ball in a tube. You train yourself to use your brainwaves to control the fan driving air through the tube, thereby controlling the height of the ball. Of course, this is just another form of biofeedback, albeit a rather sophisticated one. You have the audio cue of the sound of the fan and the visual cue of some flashing LEDs, both of which reflect the intensity with which you are concentrating. And, of course, you have the height of the ball in the tube.



Although this may sound simple, it is actually non-trivial, because you have to teach yourself to be able to vary your level of concentration. It's not difficult to not concentrate at all (if you see what I mean – please forgive the double negative), in which case the ball falls to the bottom of the tube. Similarly, it's relatively easy to really concentrate, in which case the ball is thrust to the top of the tube. The trick is to be able to control the amount by which you are concentrating, so as to make the ball rise and fall to the desired level.

So, in the evenings, while my wife and son are watching TV, you will see me in the corner of the room playing with my mind control device. I'm still at the beginner level on the free-play mode. Once I've mastered the basic skills, I will activate the Jedi Training system, and then we'll all really be in trouble. Until next time, have a good one (and may the force be with you)!

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Catch up with Max and his up-to-date topical discussions

INTERFACE

USB-TO-SERIAL CONVERSION

A number of previous *Interface* articles have covered the subject of using Visual BASIC Express Edition to read and write data via a virtual serial port. The so-called 'legacy' ports, including the RS232C serial type, are being phased out, and are now something of a rarity on new PCs. However, using Visual BASIC Express it is possible to write data to a virtual serial port provided by a USB-to-serial converter and its driver software.

The hardware is substantially different to a conventional serial port, and the data is actually being written to and read from a USB port, but this is all handled by the converter's driver software. In Visual BASIC Express a conventional serial port and a virtual type are handled in exactly the same way.

Integrated circuits

Using a separate USB-to-serial converter is a very easy way of handling things, but it is also a slightly clumsy approach. It would be neater to have the converter merged with the hardware of the main project, and this would also make it easier to utilise the +5V supply of the USB port. This supply is not made available by a USB-to-serial converter, and there is no supply output on an RS232C serial interface. This makes it necessary to use a second USB port as the power source, or to give the project its own battery or mains power supply unit.

Another advantage of merging the converter with the main project is that it will usually be possible to avoid the need for the level shifting associated with RS232C serial interfaces. The RS232C signals are at nominal levels of plus and minus 12V, although the actual signal voltages vary widely from one RS232C port to another, and are also dependent on the degree of loading. The main electronics normally works at standard 5V logic levels, and it is therefore necessary to have level shifting circuits to interface the ordinary logic circuits to the RS232C interface.

There is no point in providing a shift from standard logic levels to RS232C levels and then back to normal logic potentials again when the serial interface and the main project are in one unit. The reason for using the higher signal voltage and signals of opposite polarity is that it makes it easier to provide links over long distances at high baud rates. This is clearly not a consideration in the current context.

Serial chips

The easy way of incorporating the USB-to-serial conversion in a project is to use one of the chips that are dedicated to this function. The two chips that will be considered here are the FT232RL and

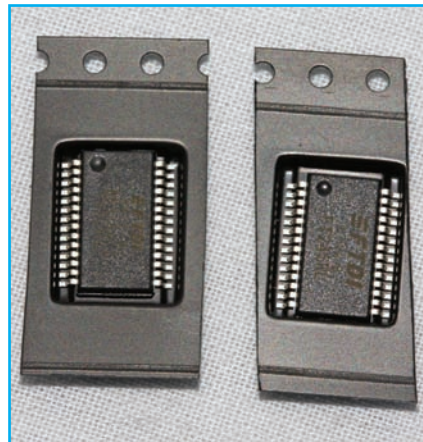


Fig.1. The FT232RL and FT245RL chips are surface-mount types that have 0.65mm pin spacing, and are tiny. The plastic case is fractionally more than 10mm long.

the FT245RL, which are produced by FTDI, and are available from Farnell or RS Components.

The FT232RL is a true USB-to-serial converter, and it provides an easy way of interfacing a microcontroller, such as a PIC chip to a USB port. The FT245RL is described by the manufacturers as a FIFO (first in, first out) chip, and it is effectively a parallel version of the FT232RL. This can also be used to interface a microcontroller to a USB port, but it is also potentially of use in relatively simple equipment that uses some conventional control logic instead of a microcontroller.

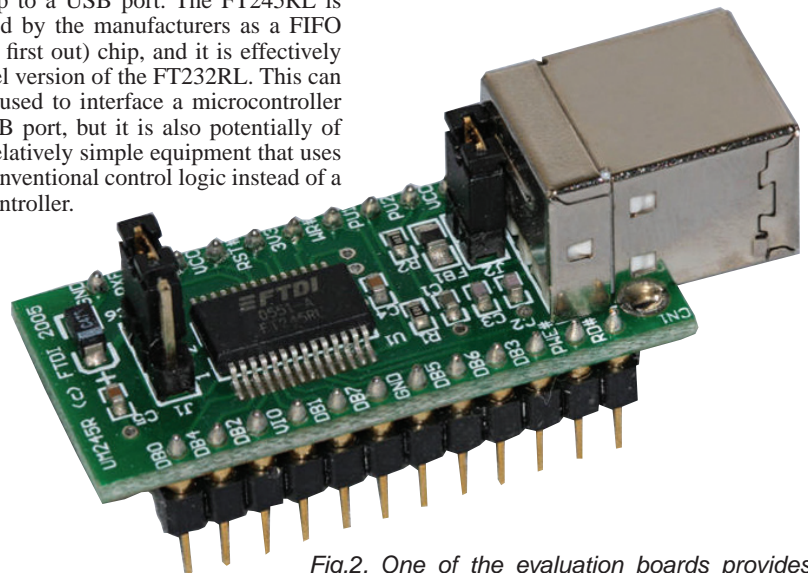


Fig.2. One of the evaluation boards provides a relatively easy way of using an FT232RL or FT245RL. This one is the evaluation board for the FT245RL

Direct drive

There are two types of driver software for these chips, and they are both available as a free download. They are also royalty free, so there are no problems if you need to distribute them to a third-party, along with a piece of hardware that utilises one of the FTDI chips.

The direct USB driver, as its name implies, enables the programmer to directly control the chip. This method has its advantages, such as a faster maximum data transfer rate, and it enables the full potential of the chips to be realised, but the software side of things seems to be something less than straightforward when using this driver.

The alternative is the VCP (virtual com port) driver, which enables data to be written to and read from the chips as if they were conventional serial ports. This is the only type of driver that will be considered here.

One slight problem with these chips is that they are not produced in an easy-to-use DIL version, making it necessary to contend with surface-mount versions and their 0.65mm pin spacing (Fig.1). For those unwilling to wrestle with tiny surface mount chips there is a way around the problem, and that is to buy the evaluation boards that are available for both chips.

Fig.2 shows the evaluation board for the FT245RL and this contains a basic circuit, complete with a USB connector. The latter enables the board to be connected to a computer using an ordinary A-B USB cable. The board has two rows of pins on a 0.1-inch pitch that provide easy access to the input/

output terminals of the chip, the supply lines and the reset terminal.

Ins and outs

Pinout details for the FT232RL and FT245RL are shown in Fig.3. The main difference between the two is that the FT232RL has serial input and output pins,

plus the various handshake lines associated with the RS232C interface, whereas the FT245RL has an 8-bit bidirectional data bus (DB0 to DB7). The FT245RL also has some control inputs and status outputs that are used to ensure that data flows into and out of the chip correctly, with conflicts on the bus being avoided.

FT232RL

Starting with the FT232RL, pins 15 and 16 are the plus and minus USB inputs respectively. These have internal series resistors and external resistors are, therefore, unnecessary. Pin 19 is the Reset input, and it is taken low to reset the device. However, there is an internal reset circuit that initialises the chip when it is powered up, so this pin is normally connected to the V_{CC} rail or left unconnected.

Pin 27 (OSC1) and pin 28 (OSC0) are respectively the input and output of the clock oscillator if an external 12MHz resonator is used, but in normal use the internal clock circuit is used and these two pins are left unused. The TEST input at pin 26 is not required in normal use either, but it *must* be connected to the 0V supply or the device will fail to work.

The serial data is transmitted at pin 1 and received at pin 5. Pins 2, 3, 6, 9, 10, and 11 are the various RS32C handshake inputs and

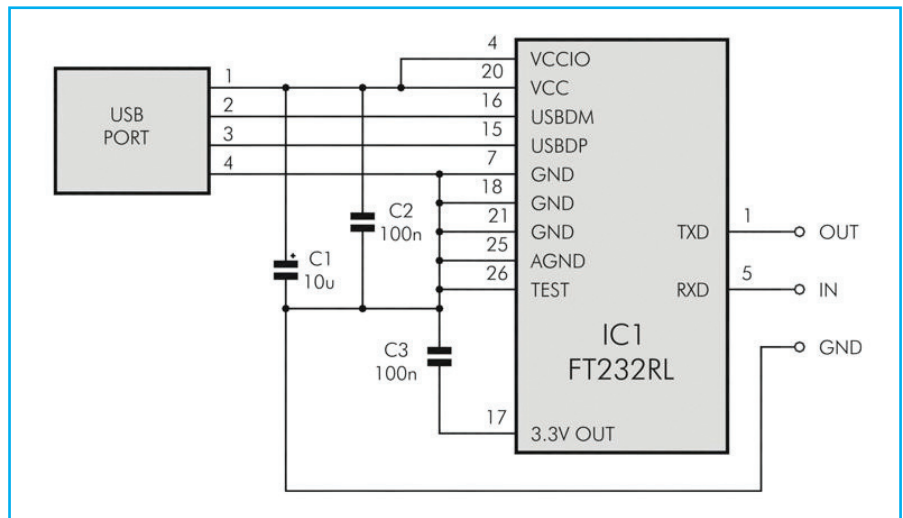


Fig.4. A basic USB-to-serial converter based on the FT232RL can be extremely simple. This circuit uses power from the USB port and has 5V logic inputs and outputs

25. The latter is the ground connection of the built-in clock oscillator.

The +5V output of the USB port connects to the VCC input at pin 20, and a ferrite bead should be used on this line. Most of the FT232RL's circuitry operates from a 3.3V supply, and it incorporates

purpose of one of these outputs should not be necessary.

In fact, they are far from essential, but three of them are potentially useful in the current context. CBUS0 (Pin 23) and CBUS1 (pin 22) are respectively pulsed low when USB data is transmitted and when it is received. They can be used to drive LEDs that will indicate when data is being sent or received on the USB port. CBUS4 (pin 12) operates as a Sleep output by default, and it goes low in the USB suspend mode. This signal could be used to power down some of the circuits in the project.

Basic circuit

Many pins of the FT232RL are left unused in most practical applications, and a simple USB-to-serial converter can be as basic as the circuit shown in Fig.4. The FT232RL (IC1) is used in the bus-powered configuration, with power being provided by the USB port. The VCCIO pin (4) is connected to the 5V supply rail, but should be connected to the 3.3V output of IC1 at pin 17 of IC1 if 3.3V compatible inputs and outputs are required.

Some users seem to find virtual COM ports problematic, and it is important to bear in mind that the right port number has to be used, and that it is unlikely to default to COM1. Use the Windows Device Manager to find details of the port, which should include its COM number.

Another point to keep in mind is that the baud rate and word format of the virtual COM port must match those used by the microcontroller or other device that the converter is being used to interface to the USB port. The FT232RL can handle baud rates from 300 baud to 3 megabaud, but getting reliable results at more than a few hundred kilobaud can be difficult when using any simple serial link.

The FT245RL is essentially the same chip as the FT232RL, but its internal program has been altered so that the input/output pins support a bidirectional 8-bit bus. As with any bidirectional bus, it is essential that the flow of data to and from the bus is correctly regulated so that a situation where there are two sets of outputs on the bus is avoided.

A detailed description of the FT245RL's inputs and outputs will be provided in the next *Interface* article.

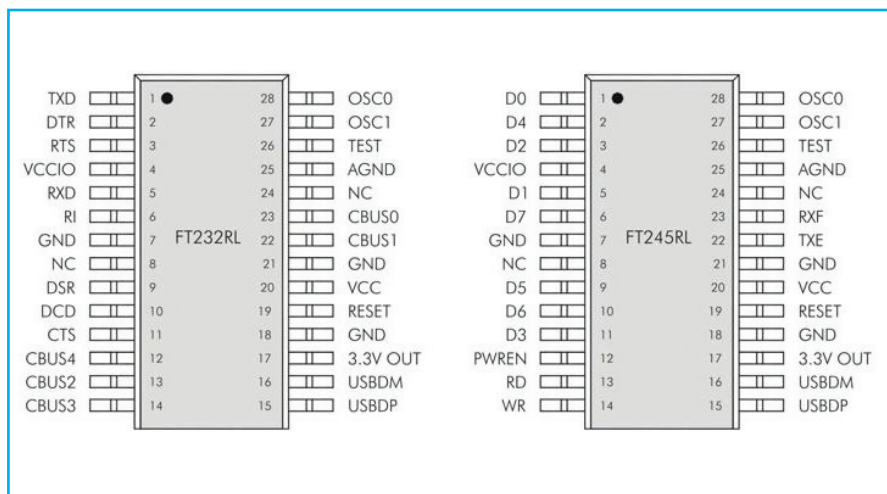


Fig.3. Pinout details for the FT232RL and FT245RL. They are housed in a SSOP-28 surface-mount encapsulation

outputs. These additional inputs and outputs are unlikely to be of any use in the current context, but the DTR (pin 2) and RTS (Pin 3) outputs are under software control when using Visual BASIC Express, which could be useful. All these inputs and outputs operate at normal logic levels, and for true RS232C operation require suitable level shifting circuits and an inversion. Level shifting is obviously unnecessary when using the device with a microcontroller. Whether signal inversions are required depends on the design of the microcontrollers serial input and output circuits, but in most cases no inversions are needed.

Bus powered

The FT232RL is normally used in its bus-powered mode, which means that it is powered from the USB output. The 0V rail of the USB port connects to the three ground terminals of the chip (pins 7, 18 and 21), and to the analogue ground input at pin

a 3.3V regulator circuit. The output of the regulator is available at pin 17, and a current of up to 50mA can be drawn by external circuits.

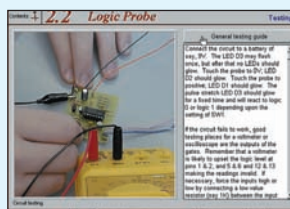
The circuit can be self-powered, and the supply connection from the USB port is then omitted. Instead, a supply in the range +3.3V to +5V is connected to the VCC and VCCIO terminals at pins 20 and 4 respectively. Whichever method is used to power the circuit, the VCCIO terminal can be connected to the 3.3V output instead of the 5V rail. The inputs and outputs of the chip will then operate at 3.3V logic levels instead of 5V levels.

In control

The five CBUS outputs have functions that are controlled by the internal program of the chip, and their functions can be altered when the direct USB driver is used. This is not possible when using the VCP driver, but changing the

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ELECTRONICS PROJECTS

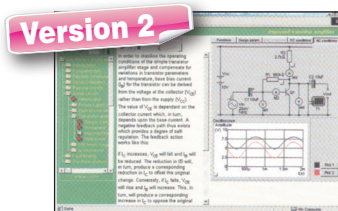


Logic Probe testing

Electronic Projects is split into two main sections: **Building Electronic Projects** contains comprehensive information about the components, tools and techniques used in developing projects from initial concept through to final circuit board production. Extensive use is made of video presentations showing soldering and construction techniques. The second section contains a set of ten projects for students to build, ranging from simple sensor circuits through to power amplifiers. A shareware version of Matrix's CADPACK schematic capture, circuit simulation and p.c.b. design software is included.

The projects on the CD-ROM are: Logic Probe; Light, Heat and Moisture Sensor; NE555 Timer; Egg Timer; Dice Machine; Bike Alarm; Stereo Mixer; Power Amplifier; Sound Activated Switch; Reaction Tester. Full parts lists, schematics and p.c.b. layouts are included on the CD-ROM.

ELECTRONIC CIRCUITS & COMPONENTS V2.0

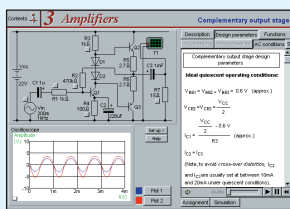


Circuit simulation screen

Electronics Circuits & Components V2.0 provides an introduction to the principles and application of the most common types of electronic components and shows how they are used to form complete circuits. The virtual laboratories, worked examples and pre-designed circuits allow students to learn, experiment and check their understanding. Version 2 has been considerably expanded in almost every area following a review of major syllabuses (GCSE, GNVQ, A level and HNC). It also contains both European and American circuit symbols. Sections include: **Fundamentals**: units and multiples, electricity, electric circuits, alternating circuits. **Passive Components**: resistors, capacitors, inductors, transformers. **Semiconductors**: diodes, transistors, op amps, logic gates. **Passive Circuits**. **Active Circuits**. **The Parts Gallery** will help students to recognise common electronic components and their corresponding symbols in circuit diagrams.

Included in the Institutional Versions are multiple choice questions, exam style questions, fault finding virtual laboratories and investigations/worksheets.

ANALOGUE ELECTRONICS

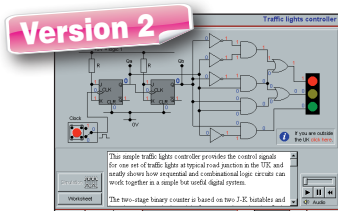


Complimentary output stage

Analogue Electronics is a complete learning resource for this most difficult branch of electronics. The CD-ROM includes a host of virtual laboratories, animations, diagrams, photographs and text as well as a SPICE electronic circuit simulator with over 50 pre-designed circuits.

Sections on the CD-ROM include: **Fundamentals** – Analogue Signals (5 sections), Transistors (4 sections), Waveshaping Circuits (6 sections). **Op Amps** – 17 sections covering everything from Symbols and Signal Connections to Differentiators. **Amplifiers** – Single Stage Amplifiers (8 sections), Multi-stage Amplifiers (3 sections). **Filters** – Passive Filters (10 sections), Phase Shifting Networks (4 sections), Active Filters (6 sections). **Oscillators** – 6 sections from Positive Feedback to Crystal Oscillators. **Systems** – 12 sections from Audio Pre-Amplifiers to 8-Bit ADC plus a gallery showing representative p.c.b. photos.

DIGITAL ELECTRONICS V2.0

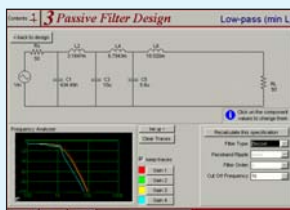


Virtual laboratory - Traffic Lights

Digital Electronics builds on the knowledge of logic gates covered in *Electronic Circuits & Components* (above), and takes users through the subject of digital electronics up to the operation and architecture of microprocessors. The virtual laboratories allow users to operate many circuits on screen.

Covers binary and hexadecimal numbering systems, ASCII, basic logic gates, monostable action and circuits, and bistables – including JK and D-type flip-flops. Multiple gate circuits, equivalent logic functions and specialised logic functions. Introduces sequential logic including clocks and clock circuitry, counters, binary coded decimal and shift registers. A/D and D/A converters, traffic light controllers, memories and microprocessors – architecture, bus systems and their arithmetic logic units. Sections on Boolean Logic and Venn diagrams, displays and chip types have been expanded in Version 2 and new sections include shift registers, digital fault finding, programmable logic controllers, and microcontrollers and microprocessors. The Institutional versions now also include several types of assessment for supervisors, including worksheets, multiple choice tests, fault finding exercises and examination questions.

ANALOGUE FILTERS



Filter synthesis

Analogue Filters is a complete course in designing active and passive filters that makes use of highly interactive virtual laboratories and simulations to explain how filters are designed. It is split into five chapters: **Revision** which provides underpinning knowledge required for those who need to design filters. **Filter Basics** which is a course in terminology and filter characterization, important classes of filter, filter order, filter impedance and impedance matching, and effects of different filter types. **Advanced Theory** which covers the use of filter tables, mathematics behind filter design, and an explanation of the design of active filters. **Passive Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev ladder filters. **Active Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev op.amp filters.



ROBOTICS & MECHATRONICS



Case study of the Milford Instruments Spider

Robotics and Mechatronics is designed to enable hobbyists/students with little previous experience of electronics to design and build electromechanical systems. The CD-ROM deals with all aspects of robotics from the control systems used, the transducers available, motors/actuators and the circuits to drive them. Case study material (including the NASA Mars Rover, the Milford Spider and the Furby) is used to show how practical robotic systems are designed. The result is a highly stimulating resource that will make learning, and building robotics and mechatronic systems easier. The Institutional versions have additional worksheets and multiple choice questions.

- Interactive Virtual Laboratories
- Little previous knowledge required
- Mathematics is kept to a minimum and all calculations are explained
- Clear circuit simulations

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PICmicro TUTORIALS AND PROGRAMMING

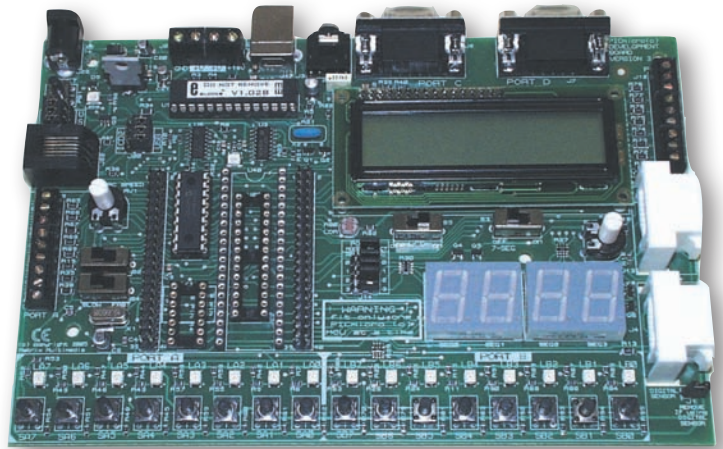
HARDWARE

VERSION 3 PICmicro MCU development board

Suitable for use with the three software packages listed below.

This flexible development board allows students to learn both how to program PICmicro microcontrollers as well as program a range of 8, 18, 28 and 40-pin devices from the 12, 16 and 18 series PICmicro ranges. For experienced programmers all programming software is included in the PPP utility that comes with the development board. For those who want to learn, choose one or all of the packages below to use with the Development Board.

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- Can be powered by USB (no power supply required)



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SOFTWARE

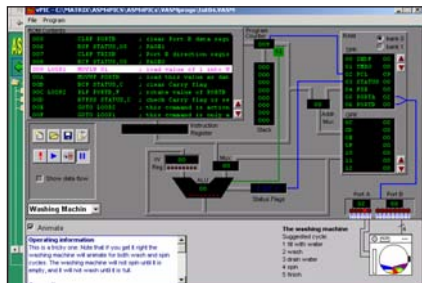
ASSEMBLY FOR PICmicro V3

(Formerly PICTutor)

Assembly for PICmicro microcontrollers V3.0 (previously known as PICTutor) by John Becker contains a complete course in programming the PIC16F84 PICmicro microcontroller from Arizona Microchip. It starts with fundamental concepts and extends up to complex programs including watchdog timers, interrupts and sleep modes.

The CD makes use of the latest simulation techniques which provide a superb tool for learning: the Virtual PICmicro microcontroller, this is a simulation tool that allows users to write and execute MPASM assembler code for the PIC16F84 microcontroller on-screen. Using this you can actually see what happens inside the PICmicro MCU as each instruction is executed, which enhances understanding.

- Comprehensive instruction through 45 tutorial sections
- Includes Vlab, a Virtual PICmicro microcontroller: a fully functioning simulator
- Tests, exercises and projects covering a wide range of PICmicro MCU applications
- Includes MPLAB assembler
- Visual representation of a PICmicro showing architecture and functions
- Expert system for code entry helps first time users
- Shows data flow and fetch execute cycle and has challenges (washing machine, lift, crossroads etc.)
- Imports MPASM files.

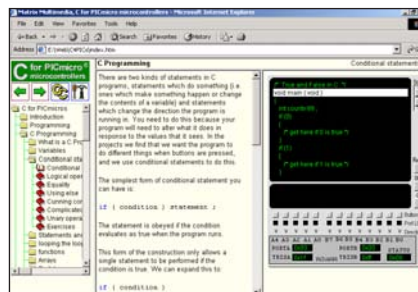


'C' FOR 16 Series PICmicro Version 4

The C for PICmicro microcontrollers CD-ROM is designed for students and professionals who need to learn how to program embedded microcontrollers in C. The CD-ROM contains a course as well as all the software tools needed to create Hex code for a wide range of PICmicro devices – including a full C compiler for a wide range of PICmicro devices.

Although the course focuses on the use of the PICmicro microcontrollers, this CD-ROM will provide a good grounding in C programming for any microcontroller.

- Complete course in C as well as C programming for PICmicro microcontrollers
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- Virtual C PICmicro improves understanding
- Includes a C compiler for a wide range of PICmicro devices
- Includes full Integrated Development Environment
- Includes MPLAB software
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Minimum system requirements for these items: Pentium PC running, 2000, ME, XP; CD-ROM drive; 64MB RAM; 10MB hard disk space.
Flowcode will run on XP or later operating systems

FLOWCODE FOR PICmicro V4

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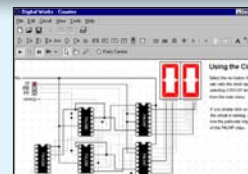
Flowcode V3 (Hobbyist/Student) – For details on Flowcode, see the previous page.

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READOUT

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Matt Pulzer addresses some of the general points readers have raised. Have you anything interesting to say? Drop us a line!

All letters quoted here have previously been replied to directly



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★ LETTER OF THE MONTH ★

Recycle it! – UV box for photo-etching

Dear EPE

For a long time I have wanted to try my hand at photo-etching, but I could never afford the UV box. So, now I am trying the following idea.

I bought one of those cheap electric flykillers (sometimes you can find them for 'buy one get one free'). I then stripped it for the UV tubes – I quickly realised I would need the drive electronics too, so I carefully removed those parts as well.

Next, I found a nice box, big enough to house the tubes and electronics, and carefully positioned the components in it. Plus, of course, some safety switches for when the lid is open (also recycled, naturally!)

My UV box doesn't have a timer yet – unlike the purpose-built ones – but they are easy enough to buy very cheaply from outlets such as Poundland.

Coming back to safety, I included a double-pole, single-throw switch with an

in-built neon indicator on the mains input, as well as fuses of course.

Bob Dakin, Sheffield

Great idea Bob, it is no secret that here at EPE we are very big fans of ingenious recycling, and I do like your idea – especially the close attention you have paid to the safety details. All readers, especially our younger ones, must be very careful when using mains-powered equipment for purposes other than its original design.

Earthing, cable rating, insulation, correct fuse selection and adequate heat dissipation are the absolute minimum requirements in any design. If in doubt, always check with someone who does understand these issues.

Bob, I hope you will be able to report back on photo-etching success and I would be delighted to hear from anyone else who is involved with similar 'home-brew' etching projects.

We hope to publish a UV Lightbox project and a feature on home PCB production in the spring.

Laptop to desktop display

Dear EPE

As a long-standing reader of *EPE*, I have often thought of articles that I would like to read, below is but one idea for use, or simply for comment from fellow subscribers.

I would be interested in finding out how to turn a laptop screen into a desktop one – fed from either a PC or Mac. I have an old Packard Bell laptop, which is near to going in the bin, but I also need a second flat screen and I would like to know how easy it would be to disconnect the screen on the laptop and feed it from a PC or Mac VGA output.

John Wilkes, by email

An interesting idea – anyone out there able to point John in the right direction to solving this question?

Front panel artwork technique

Dear EPE

After reading Robert Penfold's *Practically Speaking* article in the Jan 2010 issue of *EPE*, I thought I would share my method for creating front panels.

My technique is to follow the practice as described by Robert until printout time, when I generate precise printout on ordinary paper. I then laminate the sheet in a plastic pouch, trim to size and stick it to the drilled front panel with impact adhesive.

I do not include cut-out markers on the overlay, but simply use a knife after the glue has set to make holes.

Ed Bye, by email

Sounds like a good method to me; thank you for sharing it with us.

s-plendid explanation!

Dear EPE

I just wanted to say well done to Ian Bell for his four pages devoted to explaining the s-domain and Laplace transform (*EPE Circuit Surgery*, Oct'09).

I worked on that topic for a month when I was at university, and I never really understood it. I know some 30 years has now passed, but Ian's writing was superb and really helped me understand the issues.

Those pages really should be copied out by university lecturers and given to first-year students as background reading.

**mikeb, via chatzone,
'Poles and Zeroes' thread**

I would like to second Mike's praise. My degree was in control engineering, which is pretty much non-stop s-domain mathematics (nowadays, plus z-domain

for digital control). Many of us would have been extremely grateful to have had Ian's lucid explanation, and I certainly hope any current student readers have benefitted from it.



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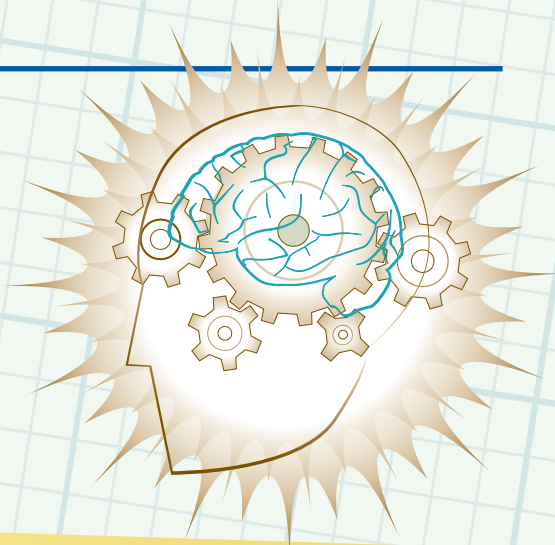
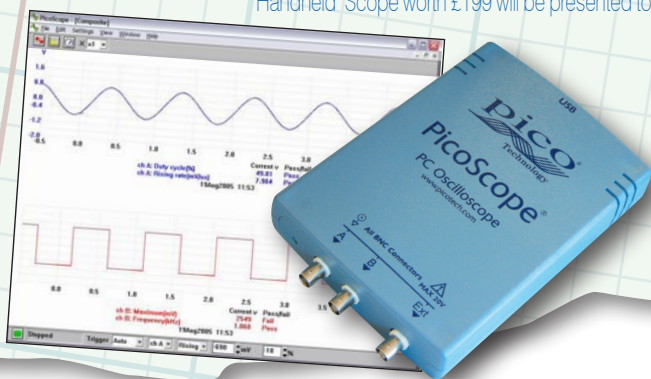
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Regulating grandfather by radio – *One for the old timers!*

My grandfather clock was made in about 1780. Successive generations have made sure that it was looked after. So the clock was reliable and kept good time – but not perfect time, because the steel pendulum was not compensated for changes in temperature. On hot summer days the clock slows down a little.

A possible solution

In an electronic frequency synthesiser, the variable frequency oscillator is kept spot on frequency by the more stable crystal oscillator. Would it be possible, I wondered, to apply a similar principle and synchronise the pendulum of my clock by making a regulator from the 60kHz time signal of station MSF from Anthorn in Cumbria – a transmission with a stated accuracy of one second in 10 million years.

Analogue MSF wall clocks can be bought from budget outlets such as Argos for about £15. I took one apart and poked about with the probe of my oscilloscope. It was a pleasant surprise to hit on a point containing a short pulse of about 1.4V every two seconds, ie, 0.5Hz. I discarded the outer case, the dial and the hour and minute hands, but left a cut-down seconds hand to indicate when the clock is locked on to MSF.

Circuit details

As can be seen from the circuit diagram (Fig.1), the 0.5Hz pulse is first amplified by two transistors configured as a Darlington pair, and then fed into the solenoid coil (L1) of an old Post-Office-type 600 relay, with its switches and armature removed. The solenoid retained some residual magnetism from its previous use; I got rid of this by repeatedly hitting it with a hammer.

The diode (D3) wired across the solenoid catches the back-EMF at the end of each pulse; and the LED confirms that the circuit is working.

The left-hand part of the circuit replaces the original battery of the MSF clock. The voltage is dropped across two silicon diodes (D1, D2)



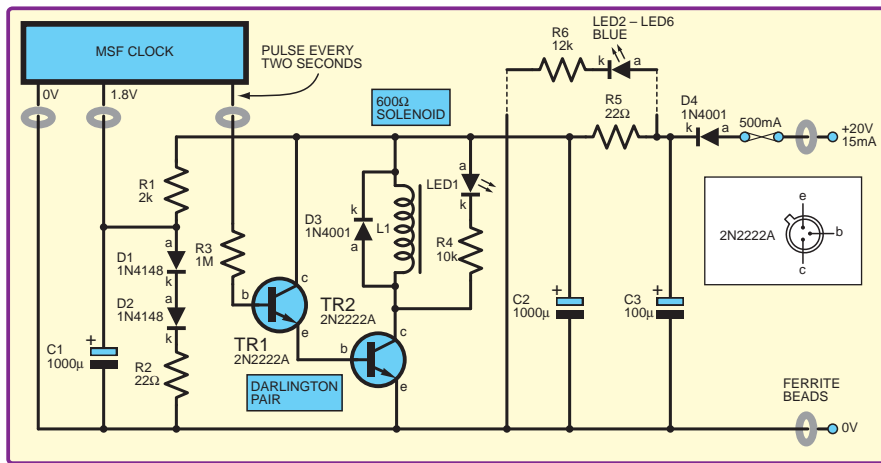


Fig.1. Circuit diagram for the radio-pulsed grandfather clock

and a series 22Ω resistor to give about 1.8V. The diode (D4) in series with the fuse is not strictly necessary; it protects the circuit from reverse polarity because I have an unfortunate habit of connecting power the wrong way round.

Testing and installation

Fig.2 shows the rig used to test that the circuit was working. The solenoid is suspended by a washbasin chain and the electronics are housed in a diecast aluminium box, just visible at the top of the photo, with the MSF clock on the left. During testing, the paper clips were suspended by a thread and held in place underneath with a rubber band. The clips twitched for each pulse from the MSF clock because a current passed through the solenoid.

After satisfactory testing, the regulator was installed inside the case of my grandfather clock (Fig.3). First, I packed out the wooden baseboard so that the centre line of the solenoid lined up with pendulum. Then, with the power off, the rest position of the regulator was adjusted by means of the bolt underneath, so that at the limit of swing the pendulum came within a whisker of touching it. Now, when the power is switched on, the pendulum is kept in sync by the attraction of the solenoid.

The driving force behind the hands is still the large lead weight in the clock. And, of course, the natural swing of the pendulum still depends on its length. Nevertheless, I have shown that the timing can be varied over a small range by an impulse at the correct frequency.

A little history

In an earlier version, the solenoid was fixed. It worked, but when the pendulum made contact with it, instead of the familiar 'tick, tick', the result was an undignified 'click, tick'. Now that the solenoid is free to move, the contact is inaudible. Also, in an earlier version, there was an emitter follower between the MSF clock and the Darlington pair, but this was found to be unnecessary.

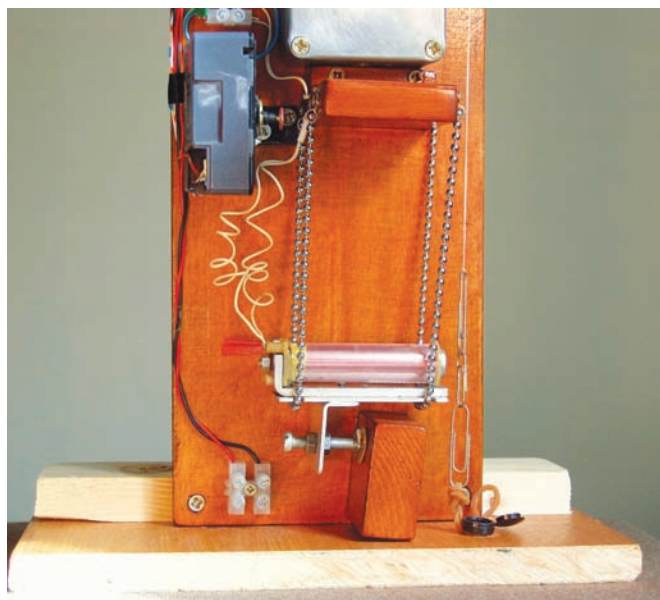


Fig.2. The regulator under test

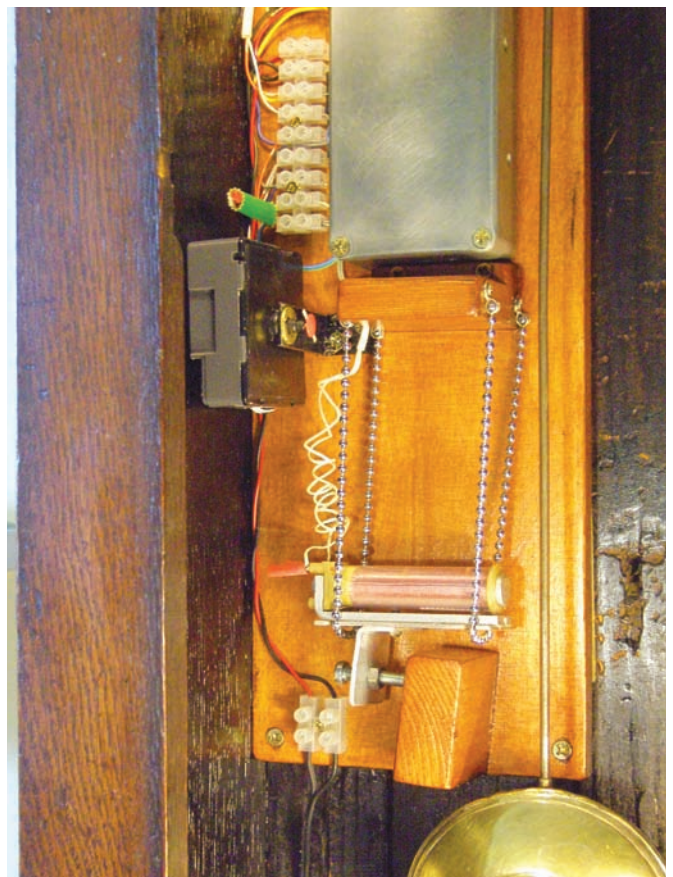


Fig.3. The 'tested' regulator fitted inside the clock case

Apart from the MSF clock, everything for the regulator was sourced from the 'spares' box. The power supply came from an old cordless phone. None of the components is critical, but note that the two diodes dropping the voltage to power the MSF clock need to be silicon to give the required voltage drop.

Father Time

In the arch at the top of the clock, Father Time, complete with his scythe, moves across the sky (see photo). The gold stars scattered about the sky were in shadow and almost impossible to see. Now that I had a power source in the clock, it was easy to illuminate the sky with five blue LEDs fitted out of sight behind the ring with its caption 'TEMPUS FUGIT' – time flies.

Accurate clock or antique

I tell the time by my grandfather clock, so I want it to be as accurate as possible. But I appreciate that another owner (and this is certainly not to imply that the clock is for sale) may wish to return it to its original 18th century condition as an antique longcase clock. Because the clock mechanism has not been changed in any way, it would merely be necessary to undo the four screws holding the baseboard of the regulator to the back of the case. And the blue LEDs behind Father Time just lift off.

British summer time

One useful feature of normal MSF clocks is that the hands adjust automatically when the hour changes each spring and autumn. But that, I'm afraid, is a trick that grandfather cannot do.

Murray Ward, Godalming

I can't remember the last time we devoted so much space to a single IU project, but I am sure readers will agree that this elegant and highly original idea is well worth it. Many congratulations Murray, this is an excellent and ingenious combination of electronics and mechanics.

Matt Pulzer, Editor

Net Work

Alan Winstanley

Online pilgrimage

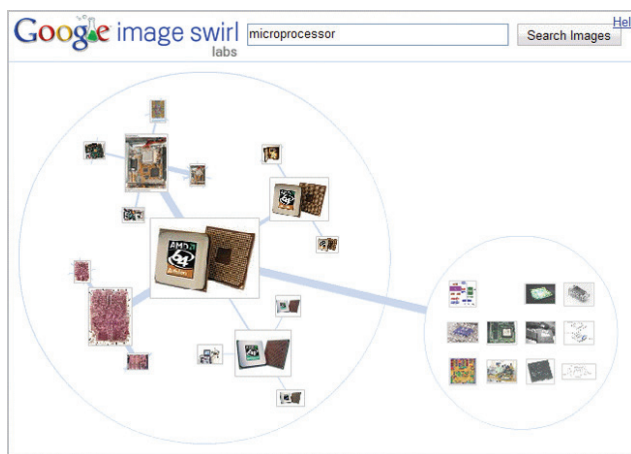
Just a few miles away from me is an English port which, history dictates, was one of the coastal inlets via which the 17th Century Pilgrim Fathers set sail for Holland and then British colonies in North America. The Thanksgiving Day festivities in the USA celebrate the original settlements of these colonies. The Friday after Thanksgiving is now known as Black Friday, which marks the traditional start of the pre-Christmas shopping bonanza; following hard on the heels of Black Friday is the new US annual event known as Cyber Monday.

The *Washington Post* reports that in 2009, some 100 million shoppers were expected to hit the web on Cyber Monday in search of Christmas bargains and gifts. In the event, web traffic rose 8% and surged nearly 20% between the hours of 5pm to midnight on Cyber Monday, the paper reports.

However, while 'virtual footfall' numbers might be up, as a sign of our recessionary times, the hunt for keen prices is more determined than ever. Never has it been easier to compare prices side-by-side, leaving customers with the headache of chasing around for reliable deliveries ex stock. Conversely, online e-tailers face logistical nightmares of managing stock controls and making timely deliveries to their customers. Even so, sales volumes did not meet expectations due to financial pressures on customers.

So, America's Cyber Monday, represents the latest milestone in the Internet's evolution. To help in our virtual quest, price comparison websites such as Ciao, Kelkoo, Pricerunner and others clog up Google's search results – type in almost any arcane product name and both technical review websites and price comparison sites are immediately listed. Quite often, eBay will have some Adwords or natural links for these items as well, no matter how obscure they may be, such is the level of refinement of online marketing.

As reported in earlier *Net Work* columns, Microsoft's Bing (www.bing.com) represents an alternative window on the world wide web. Attractive and easy to use, Bing attempts to summarise the contents of a website using a flyout accessed via a small icon (see *Net Work* Oct'09). Bing is generally a worthwhile alternative for the endless lists of blue links offered by Google.



Google Image Swirl is a fun way of navigating through a selection of search results for images



Wonder Wheels

It cannot be said that Google ever stands still though. If you want to know what Google has up its sleeve then Google Labs (www.googlelabs.com) gives a taster of things to come. Given that humans can assimilate images much more readily than screeds of text, Google *Image Swirl* is a fascinating experimental tool to play with: type in a phrase such as 'microprocessor' and the result is a slightly mindmap-like scalable graphic that interconnects bubbles of microprocessor-related thumbnail images. You can click through to other bubbles of related images which expand, before ultimately landing on the image that you're looking for.

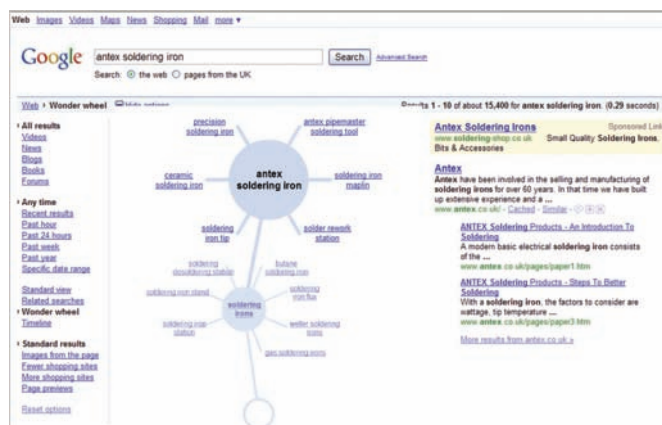
Google's Image Swirl technique is also apparent in the search engine's core results, though you will have to dig quite deeply to find it because it is part of the latest raft of web page changes implemented by Google over recent months.

A fun feature that has slipped under the radar for many Googlers is *Wonder Wheel* which is an attempt to present links in a more graphical manner, rather than boring lists of blue links, similar to Image Swirl, but using hyperlinks instead.

The way it works is this: type a search term such as 'soldering' into Google's home page and (forgive my bragging rights) my *Basic Soldering Guide* will appear near the top, along with the usual blue links. You might notice a discrete link at the top '+ More Options' which can be clicked. A sidebar will then open with numerous filter options as well as the enigmatic Wonder Wheel link. Simply launch Wonder Wheel, click the links and see what happens!

Hyperlinks will radiate out from the core search phrase, and this will spawn a new link map. My screenshots shows how links for Antex, the UK soldering iron manufacturer and regular friends of *EPE*, soon appears in the map. Google's Wonder Wheel is an alternative method of displaying search data and it points the way to an altogether more user-friendly way of presenting results. Perhaps the days of boring lists of links may be drawing to a close.

I hope you visit *Net Work* online at the *EPE* website at www.epemag.com, or why not meet fellow *EPE* readers in our *Chat Zone* forum at www.chatzones.co.uk? You can contact the writer at alan@epemag.demon.co.uk. I do enjoy reading your emails and I'm sorry if I cannot always provide an individual reply. Wishing you all a peaceful and more prosperous New Year.



Google's Wonder Wheel provides a graphical array of links that are easy to digest at a glance

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